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GREATER TAREE CITY COUNCIL

Lansdowne Floodplain Risk Management Study

For the development of a Lansdowne Floodplain Risk Management Plan

301015-02267

29 May 2015

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FOREWORD

The Lansdowne Risk Management Study utilises the work undertaken in the Lansdowne Flood Study (WorleyParsons, 2011) in combination with the process outlined in the New South Wales Floodplain Development Manual (NSW Government, 2005), to assess strategies aimed at dealing with the different types of flood risk with the study area.

The holistic objective of this process is to reduce the impact of flooding and to reduce private and public losses resulting from floods whilst avoiding the unnecessary sterilisation of flood prone land by recognising the benefits arising from its use, occupation and development.

The Lansdowne Risk Management Study identifies, quantifies and assesses all potential floodplain risk management strategies which are aimed at leading to the development of a Lansdowne Risk Management Plan by which the community as a whole is better off.

Disclaimer

PROJECT 301015-02267 - LANSDOWNE FLOODPLAIN RISK MANAGEMENT STUDY

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
1	First Draft	J Gan	D McConnell		11-May-2012		
2	Draft	J Gan/C Grant/J Merhebi	D McConnell		28-Mar-2013		
3	Final Draft	DMc	D McConnell		19 Nov 2014		
4	Final	DMc	D McConnell		29 May 2015		

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1. INTRODUCTION

1.1 Overview

Lansdowne is located approximately 15 kilometres upstream along the Lansdowne River from the confluence of the Manning River. The Manning valley was first settled in the early nineteenth century and due to the importance of streams as transport routes for primary produce, numerous settlements were located adjacent to rivers below the tidal limit. In this way, the village of Lansdowne is located close to the tidal limit of the Lansdowne River, which is approximately two kilometres downstream from the railway bridge at Lansdowne. At the 2006 census, Lansdowne had a population of 433 people.

Lansdowne village is located in the interfluve between the Lansdowne River and Cross Creek. The numerous gullies in and around the town indicate the alluvial origin of the land with the majority of the developed town elevated between 5m AHD and 15m AHD.

The greater Manning valley catchment drains an area of approximately 8000 km^2 with the Lansdowne sub-catchment comprising approximately 215 km^2. The Manning catchment extends over 175 km inland from the coast with the upper catchment regions being generally mountainous, undeveloped and elevated up to above 1200m AHD. The Manning River catchment is surrounded by the Hasting and Peel Catchments to the north and the Hunter and Karuah Catchments to the south.

The Lansdowne River catchment consists of a heavily forested and mountainous upper catchment which transitions to a mostly flat lower catchment comprised of grazing paddocks for the beef and dairy industries, and bushland.

In the Manning Valley's 180 years of European settlement, many floods of varying severity and impact have been recorded. However in this time, none have conclusively been estimated to have exceeded an Annual Exceedance Probability (AEP) of 1% (that is, an Average Recurrence Interval (ARI) of 1 in 100 years). For the Manning Valley as a whole, the largest floods were approximately equal to a 1% AEP and occurred in July 1866 and February 1929. More recent floods of moderate magnitude have occurred such as in 1978 and 1990. The 1978 flood in particular was one of the largest floods of recent history in the Manning Valley (estimated to be between a 2% and 1% event) which required the evacuation of residents and led to substantial property damage through large parts of the catchment.

The Lansdowne Flood Study, undertaken by WorleyParsons in 2011, (herein referred to as the "Flood Study") developed a RMA-2 Model that was successfully calibrated and verified against historic data and previous studies. This provided simulated flood data for Lansdowne, information on the hydraulic nature of flooding in this region and the hazards that exist. This constituted a major step in the floodplain management process with the next stage involving the detailed examination of flood risk and a range of floodplain mitigation options.

1.2 Objectives

This floodplain management study aims to generate, weigh and cost a set of options that will potentially address the different types of flood risk in the study area. The benefit of these management strategies will be ascertained by reference to the cost of doing nothing, that is, the long term cost of flooding to the wider community.

The overall objective of this Floodplain Risk Management Study (FRMS) is to provide the mechanism by which an appropriate mix of management measures can be selected as part of a Floodplain Risk Management Plan to collectively mitigate or manage the flood risks.

Flood Risk Management options are divided into the following categories:

- **Existing Risk Management**; involves ensuring that existing development is compatible with flood risk. Flood modification measures are the traditional means of mitigating damage to existing properties to an acceptable level. In addition, measures such as land use controls and flood readiness education can also be used to reduce existing flood risk. All these flood modification measures have associated environmental, economic and social costs that require evaluation.
- **Future Risk Management**; involves measures that ensure that future development is compatible with flood risk. Property modification measures, such as land use and development controls are typically the most effective means of doing this and must be evaluated based on the common good of the community as a whole.
- **Continuing Risk Management**; 1% AEP flood event is commonly adopted as the basis for flood risk management strategies. This leaves the possibility that strategies developed to manage flood risk may be overwhelmed by larger flood events, up to the PMF equivalent event. Therefore, response measures must be developed to deal with this risk. Typical measures include readiness, response and recovery plans.

The Floodplain Risk Management Study must objectively evaluate all possible strategies that will manage the aforementioned flood risks to acceptable levels. In order to be successful, the study will:

a) be congruent with any relevant, current Greater Taree City Council flood risk management policies, strategies or planning instruments;

b) gather community input, enable participation in the decision making process and gain acceptance of the management study findings;

c) determine the hazard categories within the study area;

d) identify and assess floodplain risk management measures for existing developments aimed at reducing the social, environmental and economic loss of flooding, both existing and future;

e) assess the impacts of proposed management measures

1.3 Study Area

The Study Area for the completion of the Lansdowne Floodplain Risk Management Process consists of the extents of Lansdowne Village and its immediate surroundings (Figure 1). A closeup of the Lansdowne township is provided in Figure 2.

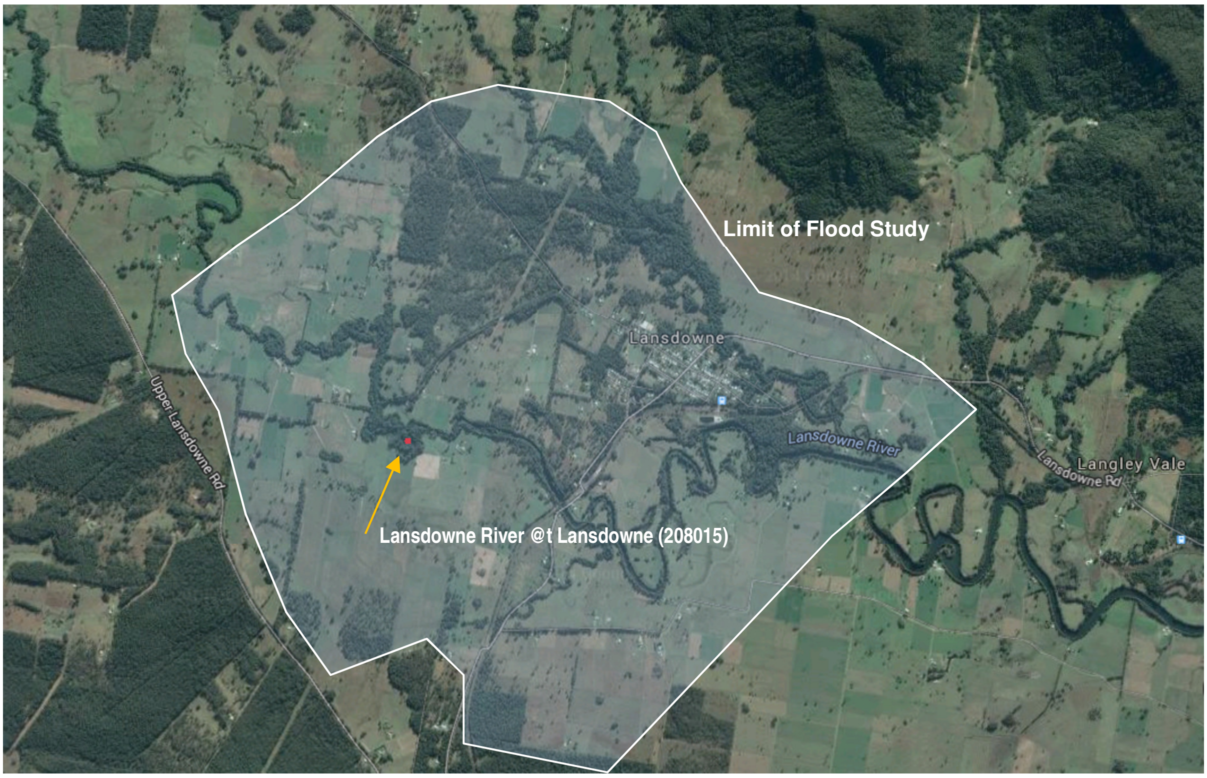

Figure 1: Study area, including location of Lansdowne River Gauge @ Lansdowne

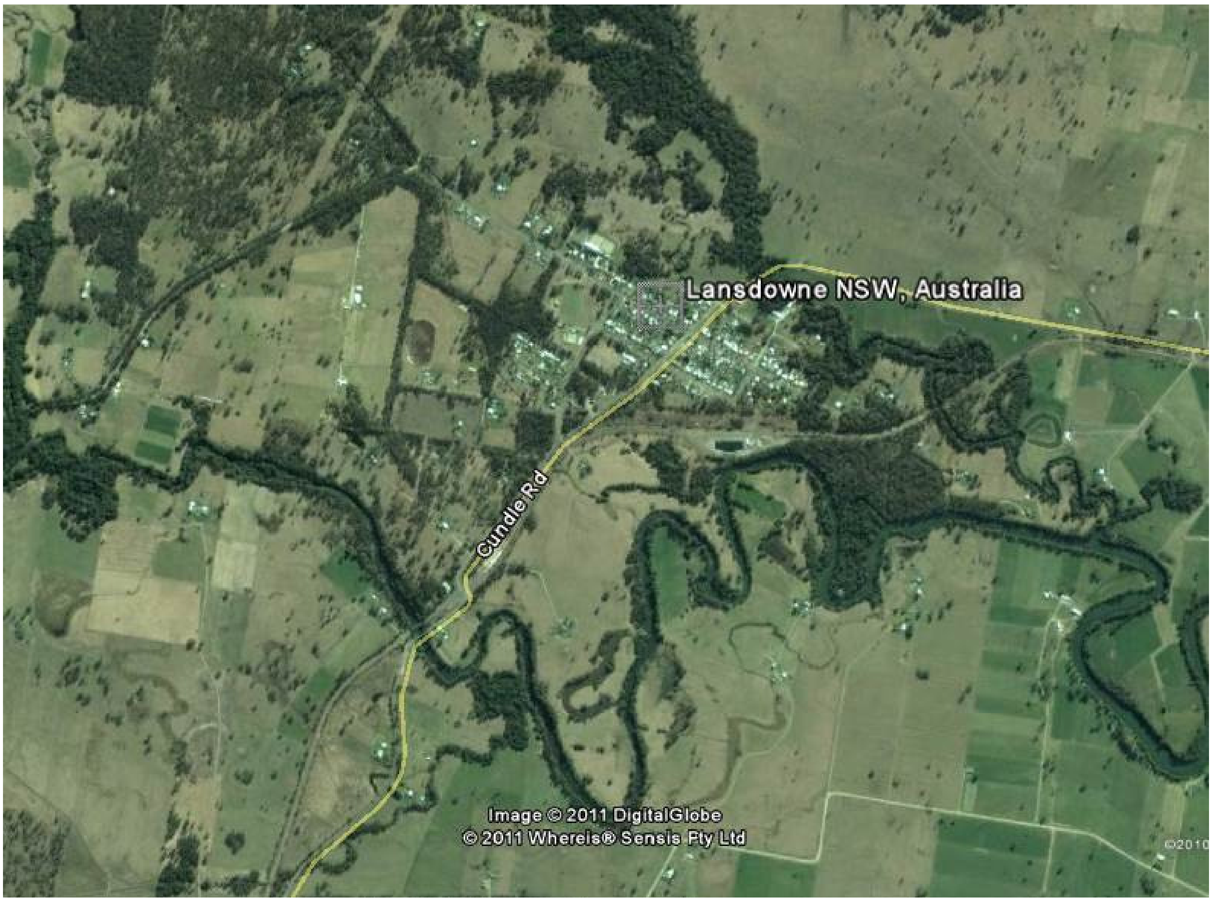

Figure 2: Approximate extent of Floodplain Risk Management Study Area (however the hydrologic and hydraulic components of this study extend over a much larger area)

1.4 Flood History

The "*Manning River Flood History 1831-1979*" (Public Works Department New South Wales) summaries recorded flood data for the Manning Valley. The majority of data available relates to Wingham and Taree and "significant" floods are defined as those reaching a peak height of 3.3m AHD at Taree and/or 10.6m AHD at Wingham. Extremely limited data for the Lansdowne River exists prior to 1969, when a gauge was installed at approximately the tidal limit (several kilometres upstream of Lansdowne village). The earliest flood record for the Lansdowne River is for the flood of 1929, which is generally regarded as one of the largest floods in the Manning Valley since European settlement.

All available data for the region was extracted with flood levels prior to 1969 taken from the "*Manning River Flood History 1831-1979*" and flood levels after 1969 extracted direct from archived gauged data held by the NSW Office of Water (*# 208015*). This data revealed that "significant" flood levels at Lansdowne were not necessarily linked to those at Wingham or Taree. This is supported most prominently through the 1978 Manning Valley flood event which occurred from the 18th of March. Intense widespread rainfall in the upper catchment led to some of the highest flood levels on record in much of the Manning River floodplain however upstream along the Lansdowne River levels were relatively minor. From the 23rd of March 1978, a more localised storm cell affected the Lansdowne sub-Catchment leading to peak levels in the Lansdowne River that were at least 0.6 metres higher than had occurred in the week prior and this event had a greater impact on Lansdowne Village than the well-known 1978 Manning Valley Flood Event. The latter storm did not adversely affect the greater Manning Catchment.

Another albeit less extreme example of this occurred in March 1995, when the Lansdowne gauge recorded its highest level since it was installed. Conversely, this flood was a “minor” flood for Wingham, Taree and the majority of the greater Manning Catchment.

These weather events imply that flooding in Lansdowne is sensitive to variations in local rainfall compared with the Manning Catchment as a whole.

Prior to 1969, flood levels for “significant floods” had been recorded at Coopernook Road Bridge, Coopernook village, Langley Vale and Moto which provides some measure of the magnitude of flood levels likely to have been experienced in the area of Lansdowne village. These flood levels, where available, were converted to approximate levels at Lansdowne by estimating a typical water surface slope between locations.

A flood level of 7.0m AHD was selected as a “significant” at Lansdowne gauge (located several kilometres upstream of Lansdowne village), because this would cause some floodplain inundation and affect properties in low lying regions based on the available flood history and elevation data (as mentioned, the majority of Lansdowne village occupied by residential development is elevated between 5 and 15m AHD).

Figure 3 shows the date and level of these “significant” flood events (NB: prior to 1969 floods were recorded based on their impact in the Manning Catchment and therefore flood events that predominantly involving the Lansdowne Catchment alone are likely to have been omitted).

From this information, at least 25 floods exceeding 7.0m AHD have occurred in the region of Lansdowne since 1929.

The four largest floods recorded at the Lansdowne gauge occurred in 1929, 1995, 1930 and 1974 with a peak level[1] of 10.3, 9.8, 9.7 and 9.4m AHD respectively.

Large floods are most likely to occur as a result of the summer to autumn cyclonic weather pattern encountering the region illustrated by the fact that nearly one third of floods exceeding 7.0m AHD were recorded in the month of March.

[1] The peak levels are reported at the position of gauge 208015 which is located several kilometres upstream of Lansdowne village. The peak levels prior to the inception of the gauge in 1969 were estimated from other locations on the Lansdowne River using average relationships between the documented points and the position of the gauge. Therefore levels prior to 1969 are only approximate.

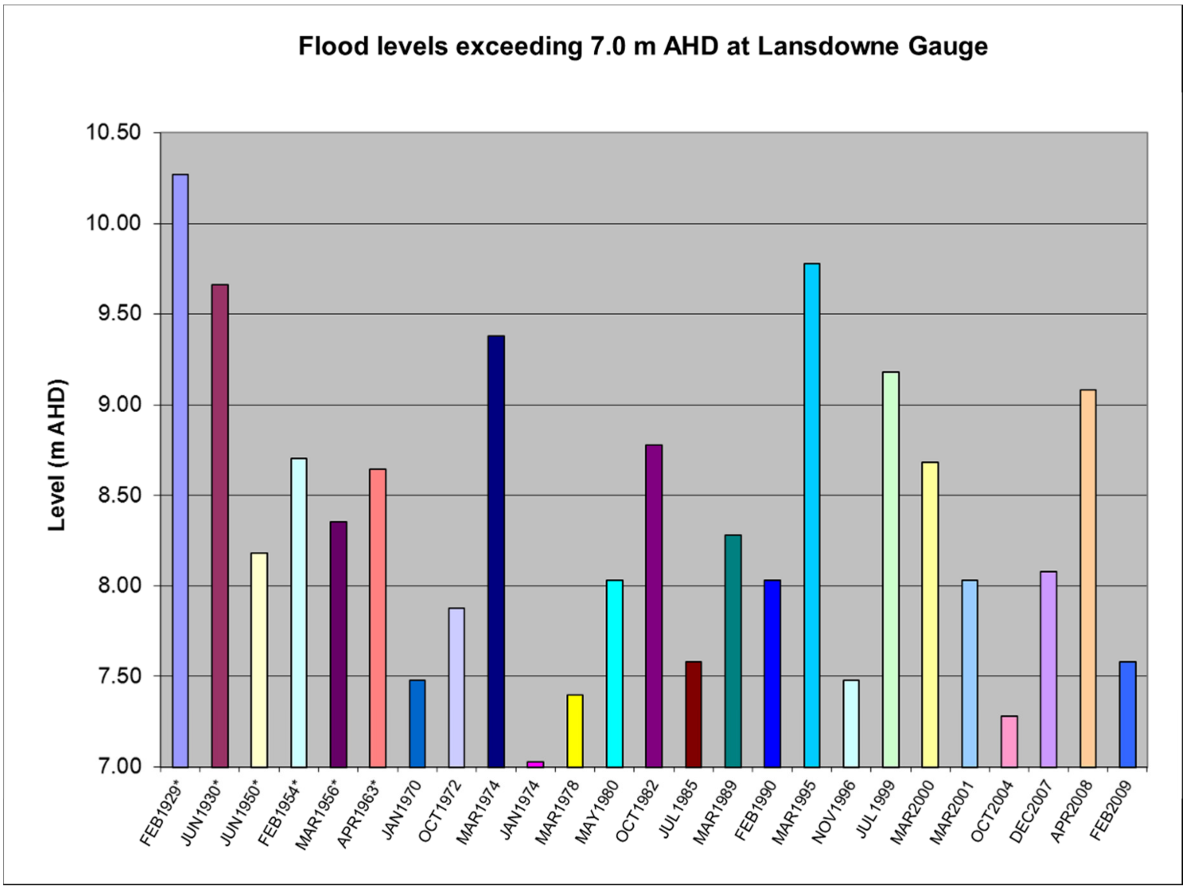

Figure 3: Floods exceeding 7.0m AHD at the location of the Lansdowne gauge (several kilometres upstream of Lansdowne village).

*Prior to 1969, levels were estimated based on records at other sub-catchment locations using average water surface slopes based on available data.

1.5 Floodplain Development Manual (FPDM) Framework

In 1986 the NSW Government released the first Floodplain Management Manual to assist in the management of flood liable land. This has been twice since revised in 2001 and 2005. The current NSW Floodplain Development Manual (FPDM) aims to optimally maintain the safe use of the floodplain whilst reducing the impacts of flooding, both publicly and privately. The most recent revision sought to ensure consistent interpretations of important strategic variables such as the flood planning level (FPL) and its interaction with rare events up to the PMF.

The FPDM provides a framework for the implementation of a policy based on the following steps:

1. Data Collection; which involves the review and compilation of all relevant data to be used
2. Flood Study; providing technical and quantitative information on flooding in the study area

3. Floodplain Risk Management Study; determining options in consideration of social, economic and ecological factors relating to flood risk
4. Floodplain Risk Management Plan; a selection of options from the study based on community and council endorsement, that will reduce flood risk
5. Plan Implementation; where flood, response and property modification measures are implemented and data collection and monitoring are continued.

1.6 Data Collection

The following list comprises local and region studies / policies that have relevance to the development of a Lansdowne Floodplain Risk Management Study

- *"Lansdowne Flood Study: Review, Upgrade and Extension" (WorleyParsons; 2011)*
- *"Interim Flood Management Policy" (Greater Taree City Council; 1987)*
- *"Manning River Floodplain Management Study" (Greater Taree City Council; 1996)*
- "*Floodplain Development Manual" (New South Wales Government; 2005)*
- *SES Archive Data (State of New South Wales through NSW State Emergency Service)*
- *Development Control Plan 2010: Part E- Flooding Req. (Greater Taree Council, 2010)*

Further to these sources, a community consultation program was implemented in order to obtain input from the Lansdowne Community to ensure that strategies developed would also deal with relevant concerns of residents.

This comprised of:

- the generation of a webpage on the Greater Taree City Council website containing a summary of the objectives, process and progress of the Flood Study, Floodplain Risk Management Study and Plan
- a survey gathering information regarding flooding in Lansdowne and providing potential management strategies where reader feedback was encouraged
- a local newspaper advertisement and letter drop informing the public of the website and the survey
- an email address made available to the public for the purpose of obtaining further information and / or providing suggestions and / or feedback
- A community workshop undertaken in Lansdowne in December 2010 which enabled residents to directly input their local knowledge into the flood study and give feedback on flood issues in Lansdowne.

2. SUMMARY OF FLOOD BEHAVIOUR

From the Flood Study, the flooding in Lansdowne can be summarised as below:

- Peak levels do not vary significantly throughout Lansdowne for a given flood
- Peak flow velocities are small for the majority of Lansdowne

The Lansdowne Flood Study covers the Lansdowne Township, and includes the effect of the Manning River on tailwater levels in the Lansdowne River. The study incorporates this influence on the Lansdowne River, based on concurrency of flooding in the Manning River. Under typical flooding weather patterns, the Lansdowne catchment, being close to the coast will receive precipitation well before the upper Manning catchment, which is considerably further inland. Furthermore, the Lansdowne system will respond much faster. Whilst peak flood levels in the Manning River have the capacity to dominate the lower reaches of the Lansdowne River, at the time the Lansdowne River has peaked, the Manning River will still be rising.

The joint flow assessment in the Flood Study indicated that the relevant zone where the Manning's tailwater influence diminishes is downstream of the study area (Figure 4).

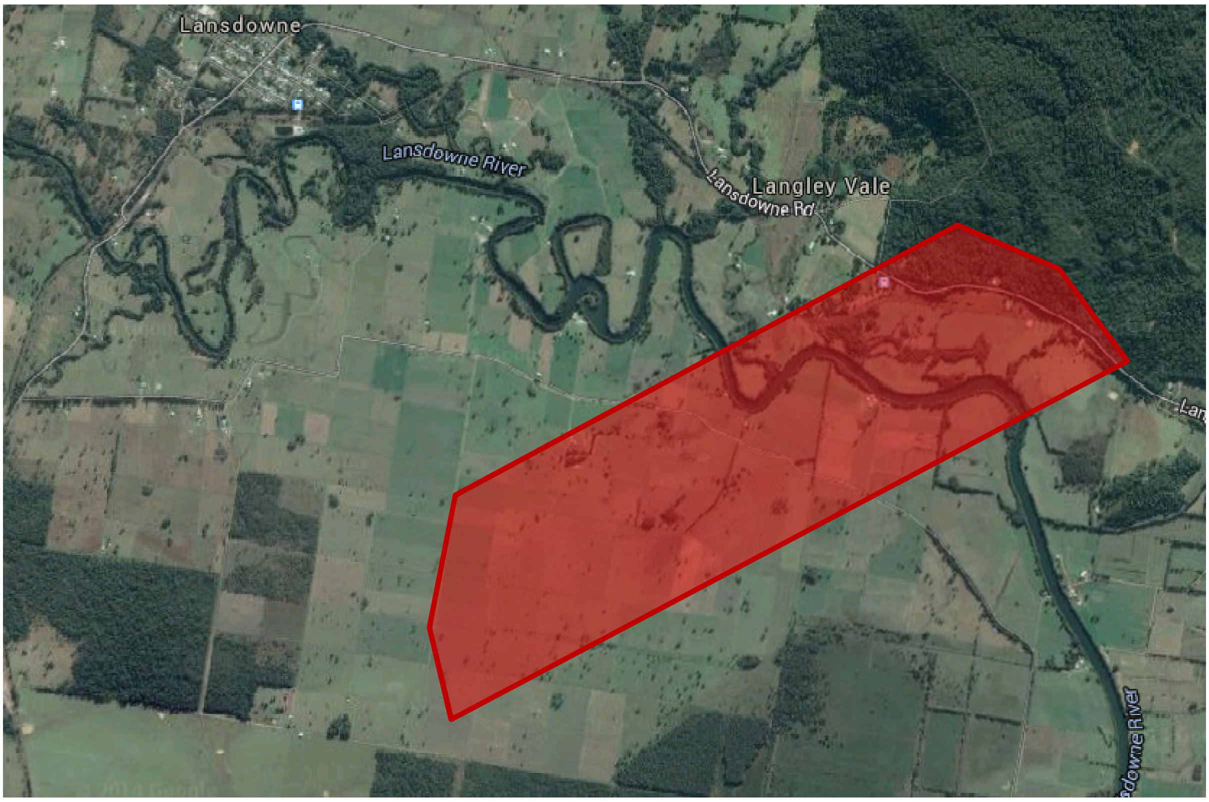

Figure 4: Indicative boundary of the Manning River tailwater influence on Lansdowne River flooding (shaded in red)

The following sections provide further details on the characteristics of flooding in Lansdowne.

2.1 Floods with an AEP of 5% or less

For more regular floods that have a 5% AEP or greater, the peak levels near Lansdowne do not exceed 6.2 metres AHD at Cross Creek, and do not exceed 5.6 metres AHD in Lansdowne River.

The following roads are inundated by flood waters (Figure 4):

- Cundle Road, from 100 metres north to 150 metres south of the Yurong Street intersection, and sections north of the Cross Creek Bridge and south of the Lansdowne River Bridge
- Yurong Street, from the Cundle Road intersection for 100 metres north
- North Moto Road, from the Cundle Road intersection for 1000 metres east
- Warrens Lane, from 100 metres east to 250 metres west of the Lansdowne River Bridge.

Lansdowne is isolated by the inundation of Cundle Road and Warrens Lane.

A portion of the rail line is inundated by overflow from Cross Creek and Lansdowne River. The inundated section is located approximately 1000m east of Lansdowne Village, where the line runs alongside Lansdowne Road.

Peak depths exceed 2 metres in the gully located near existing residential development in South Lansdowne. Flow velocity in this area is relatively low, reaching a maximum value of 0.05 m/s. This low velocity is due to the flow being backwater from Lansdowne River. Eight properties are partially inundated by this flow, with peak depths of up to 0.2 metres occurring within property boundaries. No properties are isolated by this flow.

Peak depths for Cross Creek exceed 4.5 metres near existing development in North Lansdowne. Within the banks of Cross Creek, the flow velocity is relatively high; reaching a maximum value of 1.5 m/s. Overland flow resulting from Cross Creek breaking its banks has a lower flow velocity, reaching a maximum value of 0.4 m/s. Two properties are partially inundated as a result of Cross Creek breaking its banks, with peak depths of up to 1.0 metre occurring within property boundaries. No properties are isolated by this flow.

A number of properties outside the township of Lansdowne are isolated and either partially or fully inundated by overland flow resulting from Cross Creek and Lansdowne River breaking their banks. Peak flow depths of 1.4 metres and peak flow velocities of 0.65 m/s occur within property boundaries. Properties south of Lansdowne River are isolated by the inundation of North Moto Road near the Cundle Road intersection.

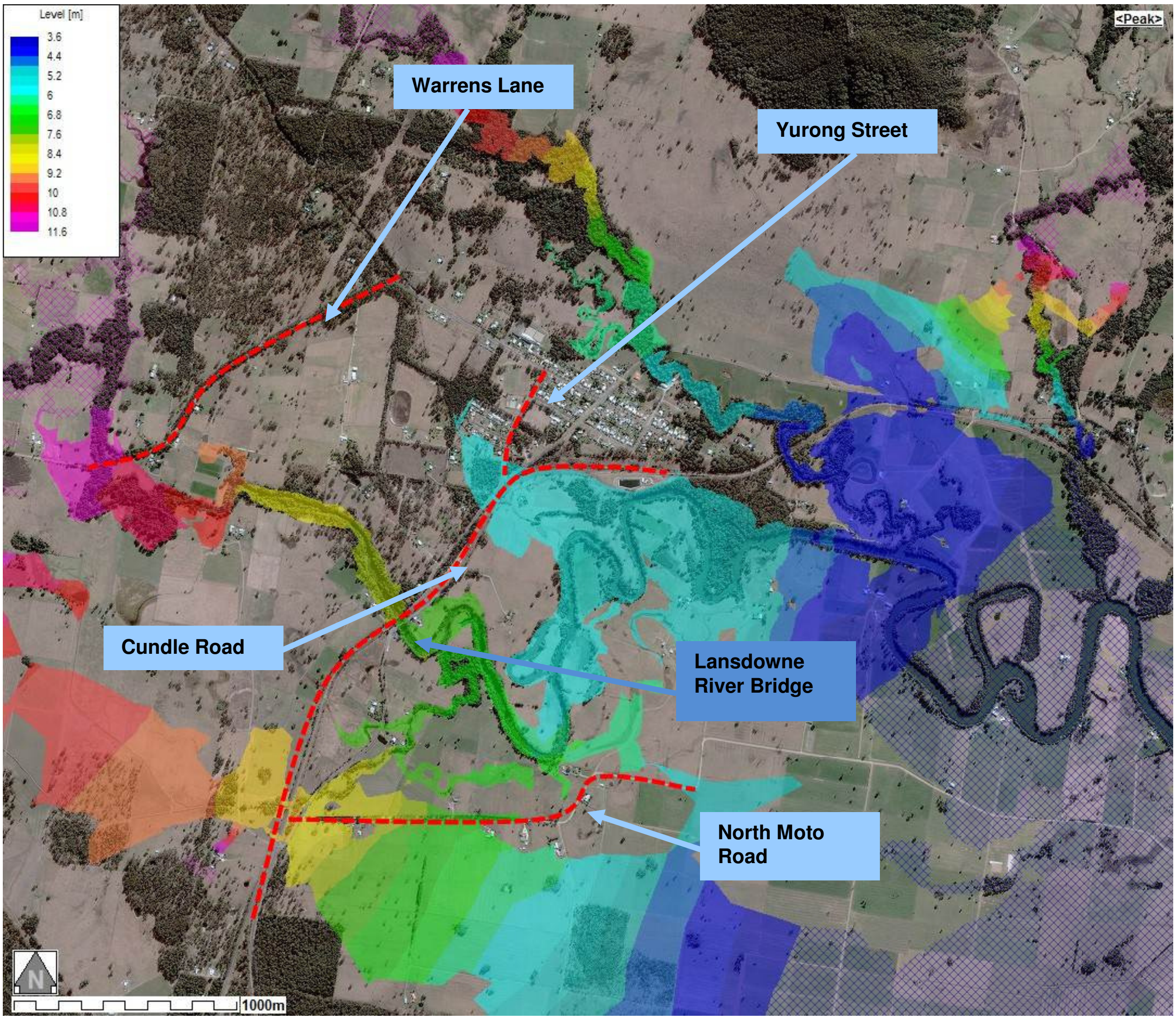

Figure 5: Flooding at Lansdowne for events up to 5% AEP

2.2 Floods with an AEP of up to 1%

For floods up to that of the FPL flood, the peak levels near Lansdowne do not exceed 6.6 metres AHD at Cross Creek, and do not exceed 5.85 metres AHD in Lansdowne River.

The roads inundated by floodwaters are of a similar composition to that discussed in the previous section, albeit to a greater extent. These roads are (Figure 6):

- Cundle Road, from 100 metres north to 200 metres south of the Yurong Street intersection, and sections north of the Cross Creek Bridge and south of the Lansdowne River Bridge
- Yurong Street, from the Cundle Road intersection for 100 metres north
- North Moto Road, from the Cundle Road intersection for 1000 metres east,

- Warrens Lane, from 150 metres east to 300 metres west of the Lansdowne River Bridge and sections further west.

The minimum freeboard attained for the Cross Creek Bridge on Cundle Road and the Lansdowne River Bridge on Cundle Road is 0.5 metres and 0.3 metres respectively.

Lansdowne is isolated by the inundation of Cundle Road and Warrens Lane.

A portion of the rail line is inundated by overflow from Cross Creek and Lansdowne River. The inundated section is located approximately 1000m east of Lansdowne Village, where the line runs alongside Lansdowne Road.

Peak depths exceed 2.2 metres in the gully located near existing residential development in South Lansdowne. Flow velocity in this area is relatively low, reaching a maximum value of 0.05 m/s. This low velocity is due to the flow being backwater from Lansdowne River. Twelve properties are partially inundated by this flow, with peak depths of up to 0.4 metres occurring within property boundaries. No properties are isolated by this flow.

Peak depths for Cross Creek exceed 5.0 metres near existing development in North Lansdowne. Within the banks of Cross Creek the flow velocity is relatively high, reaching a maximum value of 1.6 m/s. Overland flow resulting from Cross Creek breaking its banks generally has a lower maximum velocity of 0.5 m/s, with some localised areas having maximum velocities of up to 1.25 m/s. Three properties are partially inundated as a result of Cross Creek breaking its banks, with peak depths of up to 1.2 metres occurring within property boundaries. No properties are isolated by this flow.

A number of properties outside the township of Lansdowne are isolated and either partially or fully inundated by overland flow resulting from Cross Creek and Lansdowne River breaking their banks. Peak flow depths of 1.7 metres and Peak flow velocities of 1.2 m/s occur within property boundaries. Properties south of Lansdowne River are isolated by the inundation of North Moto Road near the Cundle Road intersection.

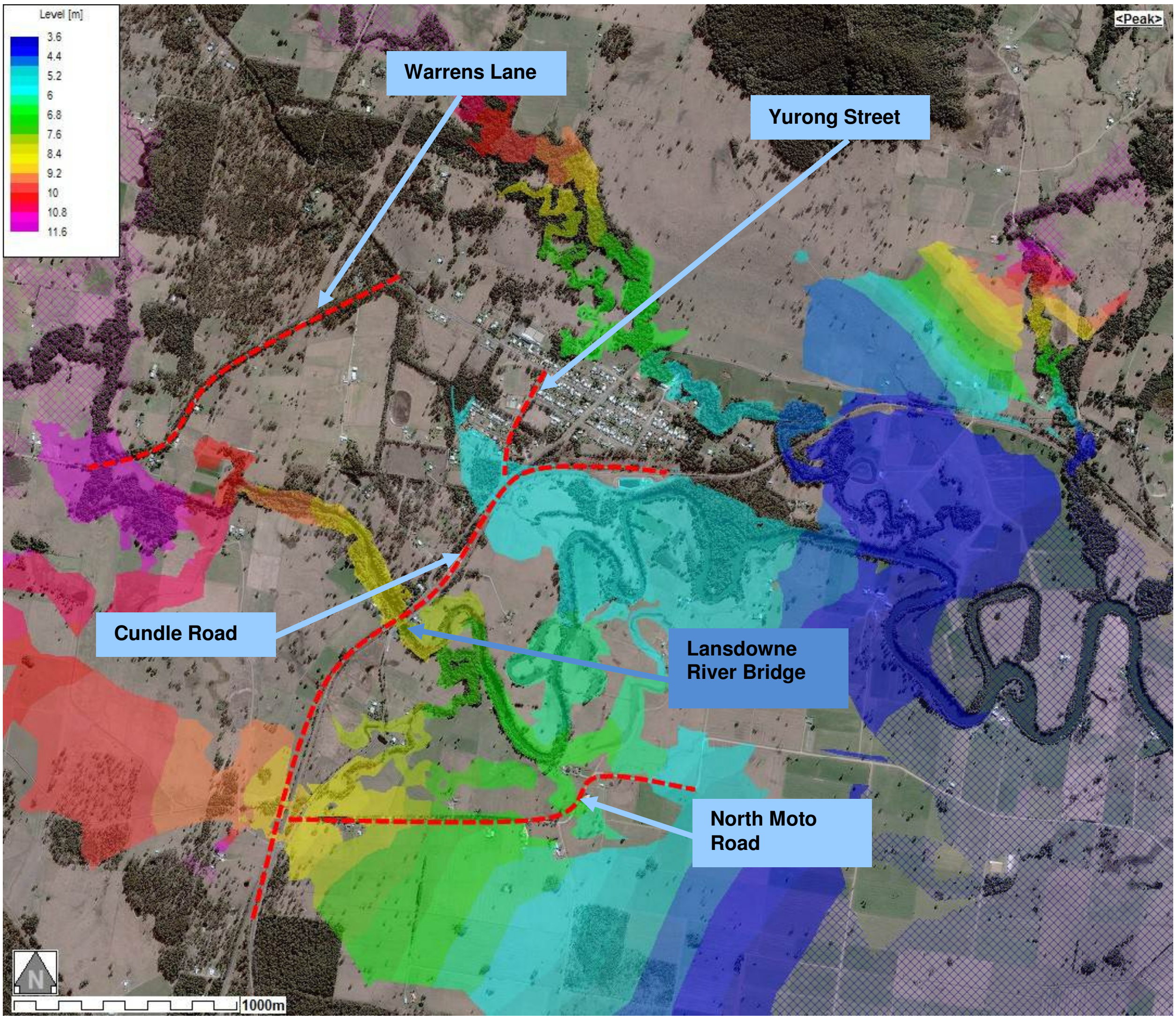

Figure 6: Flooding at Lansdowne for events up to 1% AEP

2.3 Extreme Flooding

Two distinct peaks in level occur near Lansdowne for an extreme event. This is due to the relatively short duration and high intensity of the extreme event. The first peak occurs when the high intensity rainfall exceeds the capacity of the local storage systems around Lansdowne, causing levels to rise rapidly and then fall again. The second peak occurs when the storage capacity of the Manning River is exceeded, resulting in a slow rise in backwater levels in Lansdowne River and its tributaries. In order for this second peak to occur, the design rainfall for the extreme event has to occur over the entirety of the Manning catchment. The model has not been calibrated for this, as it is outside the scope of the study. As the second peak has not been calibrated, it has not been included in this analysis.

It should be noted that an extreme event for the Manning catchment has the potential to produce levels in and around Lansdowne that are greater than those produced by an extreme event for the Lansdowne sub catchment. A flood study for the Manning catchment would be required to determine if this is the case.

An extreme event produces peak levels near Lansdowne that approach 7.7 metres AHD in Cross Creek and 6.4 metres AHD in Lansdowne River.

Large areas of land surrounding Lansdowne are inundated by flood waters. The roads inundated by flood waters are of a similar composition to that discussed in the previous section, albeit to a greater extent. These roads are (Figure 7):

1. Cundle Road
    - From 150 metres north to 200 metres south of the Yurong Street intersection, with peak depths of 1.5 metres and peak velocities of 0.1 m/s. Peak inundation occurs over a period of 2 hours, with a peak rate of rise of 1.8 metres per hour.
    - From 100 metres south of the Cross Creek Bridge for an extended distance east, with peak depths of 2 metres and peak velocities of 1.2 m/s. Peak inundation occurs over a period of 2 hours, with a peak rate of rise of 1.2 metres per hour.
    - From the railway crossing north of the Lansdowne River Bridge to the railway crossing south of the Lansdowne River Bridge, with peak depths of 2 metres and peak velocities of 2.4 m/s. Peak inundation occurs over a period of 2 hours, with a peak rate of rise of 1.6 metres per hour.
2. Yurong Street
    - From the Cundle Road intersection for 150 metres north, with peak depths of 1.5 metres and peak velocities of 0.1 m/s. Peak inundation occurs over a period of 2 hours, with a peak rate of rise of 1.8 metres per hour.
3. Hampton Court
    - From the western end of Hampton Court for 125 metres east, with peak depths of 0.35 metres and peak velocities of 0.04 m/s. Peak inundation occurs over a period of 2.5 hours, with a peak rate of rise of 0.35 metres per hour.
4. Croki Street
    - From 100m west to 100m east of the Moto Street intersection, with peak depths of 0.4 metres and peak velocities of 0.7 m/s. Peak inundation occurs over a period of 1.5 hours, with a peak rate of rise of 0.35 metres per hour.
5. North Moto Road
    - For the entirety of the road, with peak depths along the eastern section of greater than 3 metres and peak velocities near Cundle Road of 1.3 m/s. Peak inundation near Cundle Road occurs over a period of 3.5 hours, with an initially slow average

rate of rise of 0.06 metres per hour for 2 hours, followed by a much faster average rate of rise of 0.34 metres per hour for 1.5 hours.

6. Warrens Lane

    - From 150 metres east of the Lansdowne River Bridge for an extended distance west, with peak depths of 6.0 metres at Lansdowne River and peak velocities of 1.9 m/s. Peak inundation occurs at Lansdowne River over a period 3.5 hours, with a peak rate of rise of 3.0 metres per hour.

A portion of the rail line is inundated by overflow from Cross Creek and Lansdowne River. The inundated section is located approximately 1000m east of Lansdowne Village, where the line runs alongside Lansdowne Road.

The Cross Creek Bridge and the Lansdowne River Bridge on Cundle Road are inundated by 0.2 metres and 1.0 metres respectively. This, along with the inundation of Warrens Lane at the Lansdowne River Bridge, isolates Lansdowne.

Peak depths exceed 2.5 metres in the gully located near existing residential development in South Lansdowne. Flow velocity in this area is relatively low, reaching a maximum value of 0.1 m/s. This low velocity is due to the flow being backwater from Lansdowne River. Four properties at the western end of Taree Street are inundated by this flow. Peak depths of up to 1.0 metre occur within the properties boundaries. Thirteen properties in Hampton Court are completely inundated by this flow. Peak depths of up to 1.0 metre occur within the properties boundaries. Five properties in Yurong Street are inundated by this flow. One of these properties is partially inundated while the others are fully inundated. Peak depths of up to 0.8 metres occur within the properties boundaries. One property in Tinonee Street is partially inundated by this flow. Peak depths of up to 0.6 metres occur within this property's boundaries. No properties are isolated by this flow.

Peak depths for Cross Creek exceed 7.0 metres near existing development in North Lansdowne. Within the banks of Cross Creek, the flow velocity is relatively high; reaching a maximum value of 1.8 m/s. Overland flow resulting from Cross Creek breaking its banks has a lower maximum velocity of 1.1 m/s. Four properties on the northern side of Croki Street and three properties on the southern side of Croki Street are inundated by this flow. Five of these properties are partially inundated while the other two are fully inundated. Peak depths of up to 1.7 metres occur within these properties' boundaries. Eight (8) properties on Central Lansdowne Road are inundated the flow from Cross Creek. Of these, five properties are partially inundated with peak depths of up to 0.9 metres occurring within property boundaries. No property is isolated by this flow.

A number of properties outside the township of Lansdowne are isolated and either partially or fully inundated by overland flow from Cross Creek and Lansdowne River. Peak flow depths of 2.5 metres and peak flow velocities of 1.5 m/s occur within property boundaries. Properties south of Lansdowne River are isolated by the inundation of North Moto Road near the Cundle Road intersection.

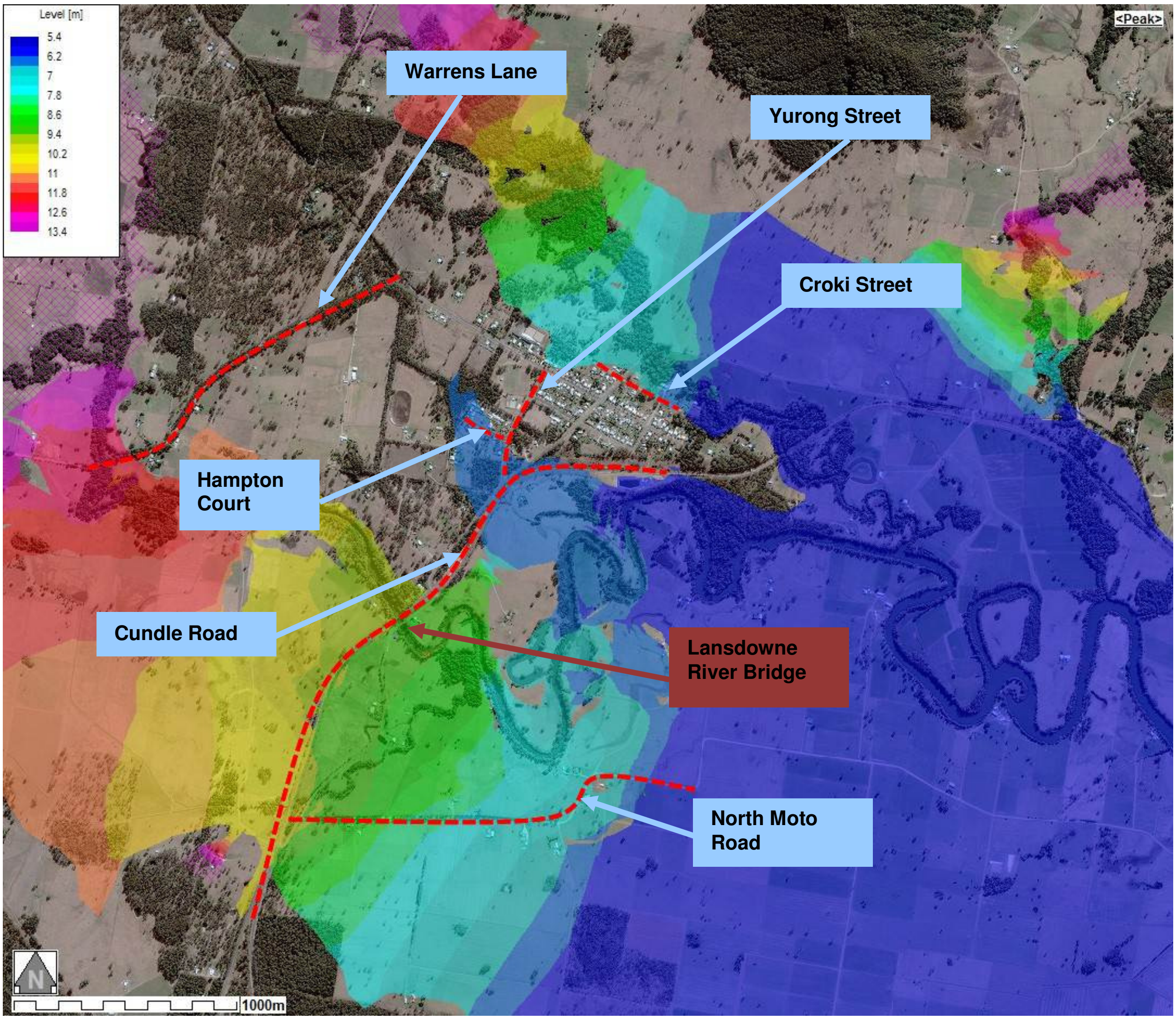

Figure 7: Flooding at Lansdowne for extreme events

3. HAZARD CATEGORISATION

Flood Hazard categorisation provides an indication as to the severity of risk and therefore which areas require floodplain risk management strategies to be developed.

A comprehensive analysis of flood hazard requires the detailed assessment of factors such as;

- Depth and Velocity of Floodwaters
- Rate of Rise of Floodwaters
- Effective Warning Time
- Effective Flood Access
- Duration of Flooding

Other important factors which are less quantitatively defined include:

- Flood Readiness
- Evacuation Problems
- Type of Development

According to the Floodplain Development Manual (Appendix L), the first step and primary influence on flood hazard is based on the depth and velocity of floodwaters – otherwise known as "provisional hydraulic flood hazard". This essentially measures the amount of energy associated with a location for a given flood.

The manual's approach to hazards involves two categories, "low" and "high". This is usually combined with a parallel hydraulic categorisation of the site, which provides a qualitative description of flood behaviour. As the Floodplain Development Manual states, it is impossible to provide explicitly quantitative criteria for defining the hydraulic categories and therefore this approach can be difficult, as well as highly subjective. These categories are utilised in the Greater Taree City Council DCP 2010.

The "Provisional Hydraulic Hazard Categories" are defined as follows:

- **Low Hazard**; depth < 1.0 m and velocity < 2.0 m/s (although with a velocity times depth limit)
- **High Hazard**; all outside this range

This is shown graphically in Figure 8.

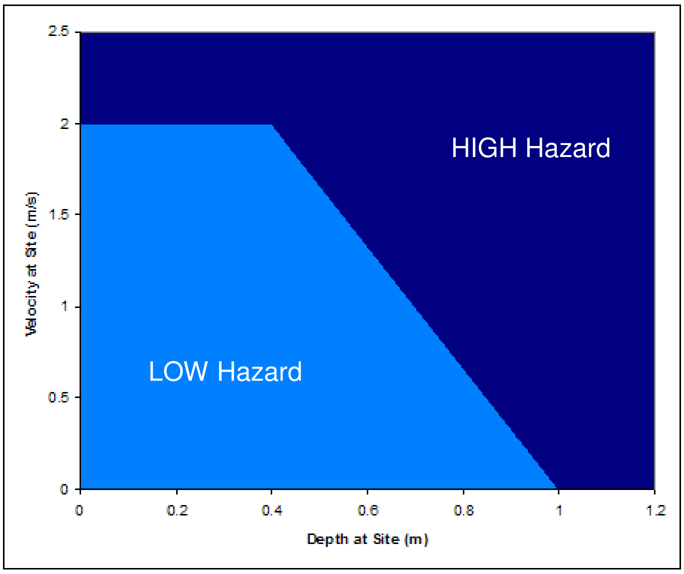

Figure 8: Preliminary Hydraulic Hazard Categories (Source: FPDM)

This provisional approach supports the categorisation of flooding at a property, i.e. via a set planning level (typically a 1% AEP event plus a 500 mm freeboard). Whilst this may limit the risk to property, the risk to life is far more complex than a single FPL. There is a need, as also stated in the Floodplain Development Manual, to consider the difficulty of the conditions that could be expected if an extreme flood occurred. Hazards can dramatically increase because of greater flood depths and velocities, and rates of rise can give little warning of dangers and the cutting off of evacuation routes.

There is also a need to consider the impact of the duration of flooding on rural areas and properties. The duration of inundation can adversely impact on grazing and cropping land. In North Lansdowne, the duration of inundation is less than 6 hours in an Extreme flood event. In South Lansdowne, within the vicinity of the study area, the duration of flooding is highly dependent on the Manning River tailwater conditions (see section 6.5, Lansdowne Flood Study). The duration of inundation in this area is approximately 8 hours. In both cases, the duration of inundation is quite short, and as such, grazing and cropping land would not be adversely affected.

Provisional Hazard Mapping based on the terminology of the Floodplain Development Manual and the Greater Taree City Council LEP/DCP consisting of areas designated with hydraulic hazards (either "High" or "Low") is included in Appendix B together with a description of the expanded approach encompassing both risk to property and risk to life.

In addition, the management of the risk to life is extended to consider the hazards associated with the full range of flood events with respect to requirements for evacuation or on-site refuge. In other words, if a site is within a zone of acceptable risk to property but becomes isolated in more extreme flooding, this can be "acceptable" if safe evacuation and / or on-site refuge can be undertaken. Obviously safe evacuation becomes the only option if hazards for rarer floods approach very high or extreme. The following is an extract from *McConnell and Low, 2001,* which describes the logic associated with risk to life:

Category 1 – *Evacuation Required* – an escape route up and away from rising floodwaters is available at all times or sufficient warning is available.

1a: *Adequate warning times available and indications of flood rise provided* – flood response plan is required for businesses and institutions. Response plan to be reviewed annually. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths where hazards become high or greater.

1b: *Rapidly rising floodwaters with no effective warning time* – rising egress route is necessary otherwise site becomes Category 2a. Flood response plan including a warning mechanism is required for businesses and institutions. Response plan to be reviewed annually.

1c: *Rapidly rising floodwaters with hazards becoming high or greater and no effective warning time* – rising egress route is necessary otherwise site becomes Category 2b. Flood response plan including a warning mechanism is required for businesses and institutions. Response plan to be reviewed annually. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths.

Category 2 – *On-site Refuge Required* – the site or area becomes enclosed by rapidly rising floodwaters with no effective warning time and no obvious escape route, or escape route is cut *(ie. becomes high hazard)* within half an hour of being flooded. Fail safe refuge is required on-site for residents/occupiers and visitors, and building must be able to withstand dynamic and static forces of floodwater plus an allowance for debris loading.

2a: *Hazard remains or becomes low to medium* – engineer's certification of structural design is required to the satisfaction of Council. May be categorised as 1b if rising egress is available.

2b: *Hazard becomes high to very high* – determination of structural design is required to the satisfaction of Council. Inspection and approval of flood resistant design is required. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths. Suitable for light construction with appropriate design modifications. Not acceptable for places of assembly or critical institutions.

2c: *Hazard becomes extreme* – determination of structural design is required to the satisfaction of Council. Inspection and approval of flood resistant design is required. Flow conveyance capacity is to be maintained without adverse increase in flood levels or disruption to flowpaths. Unsuitable for light construction. Not acceptable for places of assembly or critical institutions.

Hazard maps supporting the GTCC DCP Hydraulic Categories are shown in Figure 9. The definition of the DCP Hydraulic Categories was established using the combined property and life hazards discussed by McConnell & Low in the paper *"New Directions in Defining Flood Hazard and Development Control Planning"; 2001*. These combined or expanded hazard categories incorporate the FPDM provisional categories and further information can be found in Appendix B – FLOOD Hazards Maps. For the purposes of this Risk Management Study, the DCP Hydraulic Categories are defined as follows:

- **Low and High Hazard Flood Way:** This is the area that is bounded by the expanded category of "Extreme Hazard" in the 1% AEP flood event and represents the primary conveyance areas for flood flows.
- **High Hazard Flood Storage:** This is the area bounded by the expanded category of "High and Very High Hazard" in the 1% AEP flood event and represents areas where property and risk to life hazards are significant and the hydraulic benefits of flood storage on mitigating flood levels are important.
- **Low Hazard Flood Storage:** This is the area bounded by the expanded category of "Low and Medium Hazard" in the 1% AEP flood event and represents areas where property hazards are manageable, risk to life hazards are significant and the hydraulic benefits of flood storage on mitigating flood levels are important.
- **High Hazard Flood Fringe:** This is the area outside the 1% AEP flood extent and bounded by the expanded category of "High Hazard" or greater in the PMF flood event. It represents areas that are acceptable for property risk, but which remain significant for risk to life.
- **Low Hazard Flood Fringe:** This is the area outside the 1% AEP flood extent and bounded by the expanded category of "Low and Medium Hazard" in the PMF flood event. It represents areas that are acceptable for property risk and risk to life.

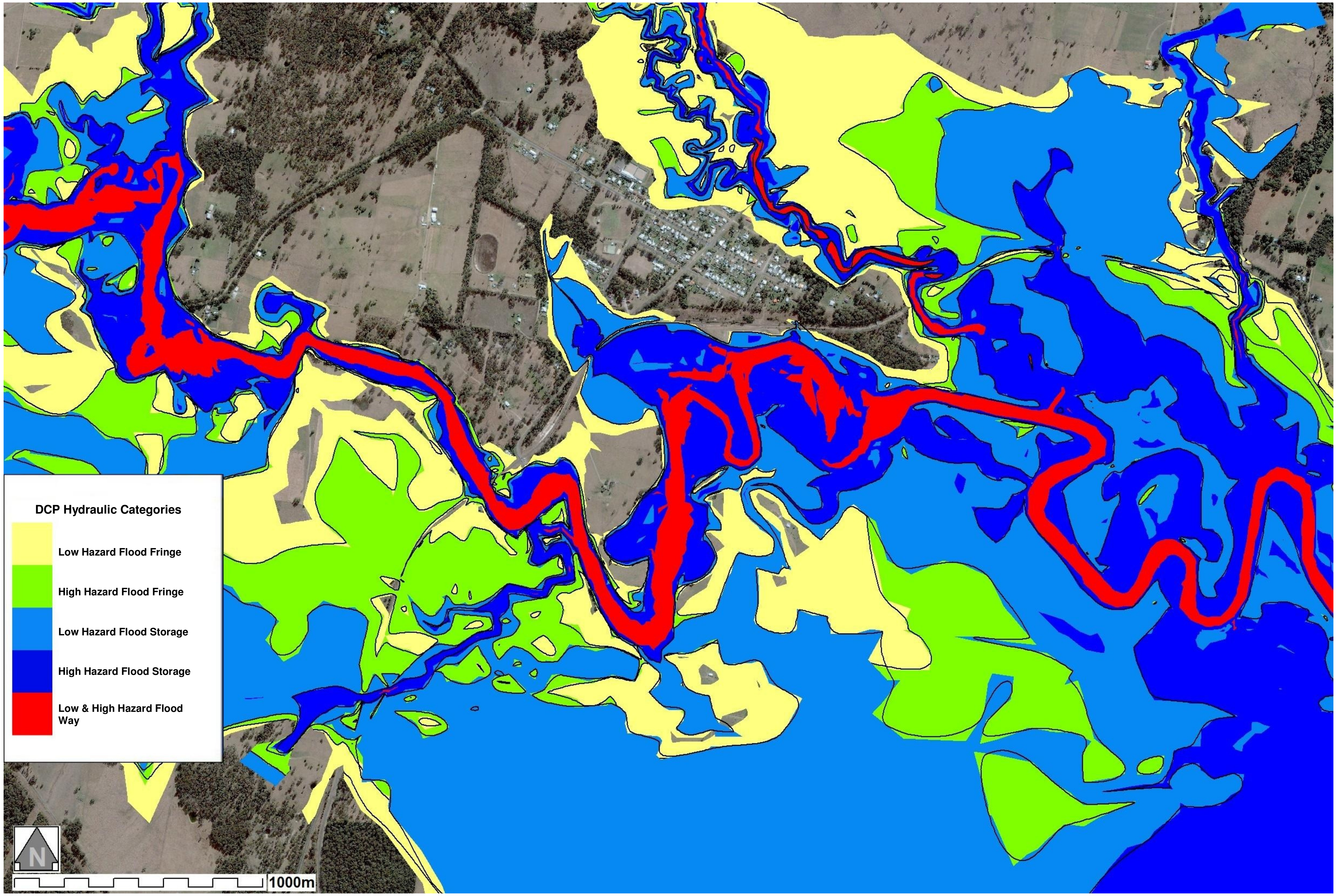

Figure 9: DCP Hydraulic Categories Map, based on the definitions in the GTCC DCP Part E: Flooding Requirements

4. CONSEQUENCES OF FLOODING IN LANSDOWNE

There are two basic components of flood damage;

1. **Tangible damages** result in direct, measureable, financial costs such as property damage but also indirect costs such as those associated with the clean up as well as financial costs such as loss of wages/business.
2. **Intangible damages** are those costs on the communities that are more difficult to quantify, such as the trauma and stress associated with flooding.

This section will outline the consequences of flooding in Lansdowne, in terms of the aforementioned flood damage categorises.

4.1 Tangible Damages

Tangible flood damages are comprised of direct and indirect costs. The direct costs may include:

- **Internal Contents Costs**; associated with the damage, repair and replacement of household contents such as furniture, electrical equipment, clothing etc.
- **Internal Structure Costs**; associated with the damage, repair and replacement of household components such as carpet, flooring, cupboards, doors, walls etc.
- **External Property Costs**; associated with the damage, repair and replacement of sheds, fences, driveways, gardens, vehicles etc.
- **External Structure Costs**; associated with the partial or complete destruction of a dwelling

The indirect costs may include:

- **Clean-up Costs**; associated with individual properties or the community as a whole
- **Financial Costs**; associated with loss of wages, sales, production

To calculate the tangible damage associated with flooding in Lansdowne the following information was used:

a) **Peak flood levels throughout the study area for the full range of design floods**

b) **Property floor levels**; there was no floor level available; assumed 0.3m above DTM ground level

c) **Lansdowne Damage Curves**; which gives the cost per increment of depth for several different types of residential properties in Lansdowne. This was estimated using the Department of Natural Resources calculation program, in combination of information from the Bureau of Statistics, Rawlinson's and data collected by WorleyParsons through site visits. This information is plotted in Figure 10.

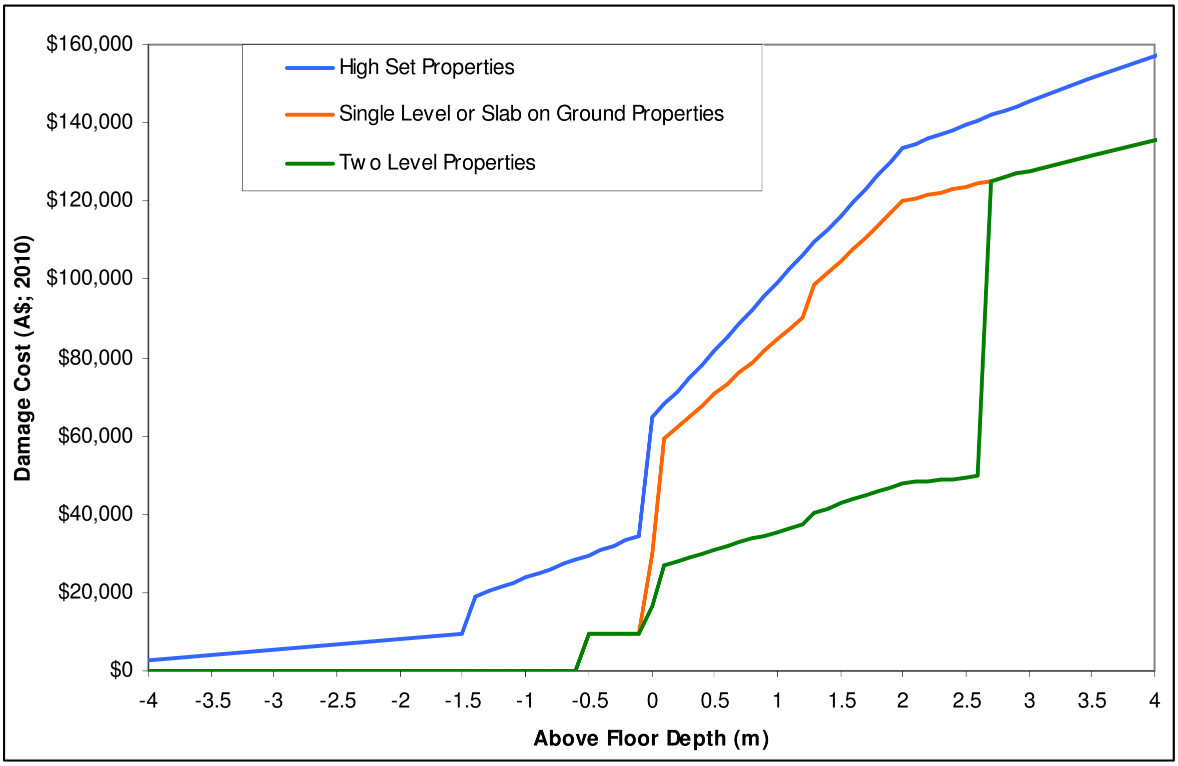

Figure 10: Lansdowne Flood Damage Curves[2]

This information provided the input into the waterRIDE Flood Manager Software package and a damage analysis performed.

Properties within the Very High to Extreme hazard categories were considered to have a chance of complete destruction due to the energy associated with the flood velocity and depth. The potential for this destruction was expressed as a range with a sensitivity of 25% and 75%; that is the actual house destruction was set at 25% and 75% of the number of houses experiencing Very High or Extreme hazard.

Table 1 shows the tangible flood damages over the range of design floods in Lansdowne.

[2] **Definitions for High Set, Single Level and 2 Level property are as follows:**

- **High Slab: Floor height > 1.5m above ground elevation**
- **Single Level: Floor height > 0.5m above ground elevation**
- **2 story: Two story house with second floor >2.6m above first floor**

Further information can be found in the document "Site Specific Inofrmation for Residential Damage Curve Development", McLuckie. D, DNR (now DECWW), vs.3, 2007

Table 1: Estimated Tangible Flood Damages in Lansdowne in 2014 dollars

Flood AEP	No. houses with over floor flooding	No. of houses within a 'Very High' or 'Extreme' Hazard	No. of houses potentially destroyed	Tangible Damages (no house destruction)	Total Tangible damages
5%	38	0	0	$1.12M	$1.12M
2%	40	0	0	$1.39M	$1.39M
1%	46	1	0	$1.76M	$1.76M
0.5%	51	1	0	$1.99M	$1.99M to $2.23M
PMF	66	15	0	$4.91M	$5.84M to $7.46M

4.1.1 Average Annual Damages

Over a long period of time, Lansdowne will be subject to a variety of floods leading to a variety of damage. The annualised average of the damaged (AAD) for all floods over a very long period of time is a useful measure of the likely long term costs of flooding in Lansdowne, and can be used to assess mitigation options and how these are likely to benefit the community.

The AAD is determined by plotting damage costs against the design flood exceedance probabilities and determining the area under the curve. The exceedance probabilities used range from 5% AEP to the PMF flood event.

Similar to common financial assessments, the present value of potential flood damages can be determined through a net present value analysis of the AAD, typically over a planning horizon of 50 years. Treasury guidelines specify a discount rate of 7% for this analysis with a sensitivity assessment of ± 3%.

Table 2 summarises the AAD over a typical 50 year period and provides a total present value in 2011 Australian Dollars (PV) using an average treasury-defined valuation change rate of 7%.

Table 2: Average Annual Damages and Present Value over 50 years for Lansdowne in 2014 dollars

	AAD	PV (7%)
Lansdowne	$110,500 to $117,400	$1.53M to $1.62M

In other words, for a typical 50-year period assuming the current level of development remains constant, the average annual cost of floodplain in Lansdowne is in the order of $110,500 to $117,400. The total present value of this over the next 50 years is between $1.53 million and $1.62 million.

4.2 Intangible Damages

Flooding imposes a range of damages on victims that are difficult to put a monetary value to. These are known as intangible damages and have proven to be significant when large floods occur. These damages are associated with the emotional, mental and physical health of flood victims and studies have shown that these damages ultimately derive from the financial and social impact of flooding but in general can be associated with:

- loss of life
- personal injuries
- disruption to the personal and work lives
- Disruption to essential services such as schools, power, water, sewerage etc.
- opportunity losses such as those resulting from the suspension of education and government services
- environmental damage

Intangible damages have the added detriment that they have been shown to potentially linger for many years after a large flood.

5. FLOODPLAIN RISK MANAGEMENT OPTIONS

General Note on Flood Access Works

In coastal regions, where floods occur over relatively small time scales, adequate flood access and evacuation is essential for managing the flood risks to life. Whilst it may be acceptable for some areas to become isolated during a minor flood, safe evacuation routes need to be available in the event of more extreme flooding. A number of areas in Lansdowne where improvements should be undertaken were identified by using the time-varying flood study data for an extreme flood.

The financial benefit of these works is difficult to measure because it would be reflected in the cost of other floodplain management options (such as Voluntary House Purchase) and flood risk to life as a whole.

The availability and any potential legal requirements of using the land proposed would need to be investigated further. Cost estimates (reasonably) assume that the land is Council-owned.

The following section outlines floodplain risk management options for Lansdowne. There are essentially three ways in which flood risk can be mitigated:

1. **Property Modification**; which deals with modifications to existing properties and controls on future development
2. **Response Modification**; which deals with modifications to the response of the population to better understand and handle the flood risk
3. **Flood Modification**; which deals with modifications to the behaviour of the flood itself

A well-rounded composition of strategies to deal with the flood risk will likely contain elements of all these categories.

Of course, the option of *"do nothing"* also exists, but the previous section showed that in the long-term, the costs of doing nothing accumulates for individuals and the community as a whole. Therefore the cost of a *"do nothing"* approach can be used to compare the cost and benefit of floodplain management options.

It should be noted that there is very limited scope for modification and control of flood behaviour. The following sections list the available options.

5.1 Risk to Property and Life Issues in Lansdowne

The management of existing and continuing flood risk are much more difficult to manage than future flood risk because of a conflict between what *should* be done with flood prone area as opposed to what has *already* been done. Therefore, before a Floodplain Risk Management options can be analysed, the risk to property and life for existing development in Lansdowne needs to be further interrogated from the results of the Flood Study.

The first step involves the results of the 1% AEP flood event, which is the basis for the FPL. Using the hazard map, in combination with the peak velocity and depth maps, it is summarised that:

1) None of the properties face a flow depth and velocity that would likely lead to partial or complete destruction of the property that is located in an area of "extreme hazard" according to the 1% AEP event (Figure). An "extreme hazard" condition compounded by partial or complete destruction of properties would represent an unacceptable risk to life for the occupants of these properties.

2) None of the properties were identified to be either partially or completely within "very high hazard" areas that also experience a flow velocity of at least 0.5m/s. Properties within "very high hazard" area compounded by moderate to high velocity with a large depth of floodwater would pose a potential risk to life or the occupants of these properties.

The second step involves the results of the PMF flood event, which represents the most extreme flood risk that exists. This event is used to evaluate the likely risk to life of the occupants and / or rescuers in the event of an evacuation. A flood level of 7.0m AHD was selected as a "significant" at the Lansdowne gauge.

Using the time-varying flood study data for depth, velocity and hazard, the following information was extracted regarding the likely number of properties that would need to be evacuated in a given time (NB: The maximum time has been based on safe wading for an able-bodied adult and therefore would be greater than the time required for vehicular evacuation, the elderly or impaired).

1) Two (2) properties, one at Cross Creek and the other at Lansdowne River are isolated very early before adequate warning based on river levels is available. These properties are isolated by flows from Cross Creek and Lansdowne River within 2.5 hours.

2) Three (3) properties in Lansdowne Village and twelve (12) rural properties would have less than 3 hours to evacuate after the SES 'Significant Flood' level was reached at the Lansdowne gauge.

3) Forty-one (41) would have at least 3 hours to evacuate after the SES 'Significant Flood' level was reached at the Lansdowne gauge.

(NB: Only properties that will be completely inundated or isolated are considered for evacuation).

A significant portion of these properties would require an SES managed evacuation or rescue due to the extreme hazards that arise if occupants do not evacuate within the required time.

In categorising these properties, it has been assumed that these properties are in their current condition, without any essential upgrade or modifications.

5.2 Property Modifications

The following Property Modification options were considered for Lansdowne:

1. Flood Access Works
2. Voluntary House Purchase (VHP)

3. Development Controls and Zoning
4. Voluntary House Raising (VHR)

5.2.1 Flood Access Works

Adequate flood access and evacuation is essential for managing the flood risks to life. Whilst it may be acceptable for some areas to become isolated for a short period during a minor flood event, safe evacuation routes need to be available in the event of pluvial flooding.

Recommended evacuation route upgrade

The location of a recommended route upgrade for safe evacuation in Lansdowne by raising an integral access route is shown in Figure 11. The raising of the low point on Cundle Rd would provide egress from the town during the early stages of significant flooding egress during minor or nuisance flooding; and rising egress to flood free land in the town and Lansdowne Road has been cut further south.

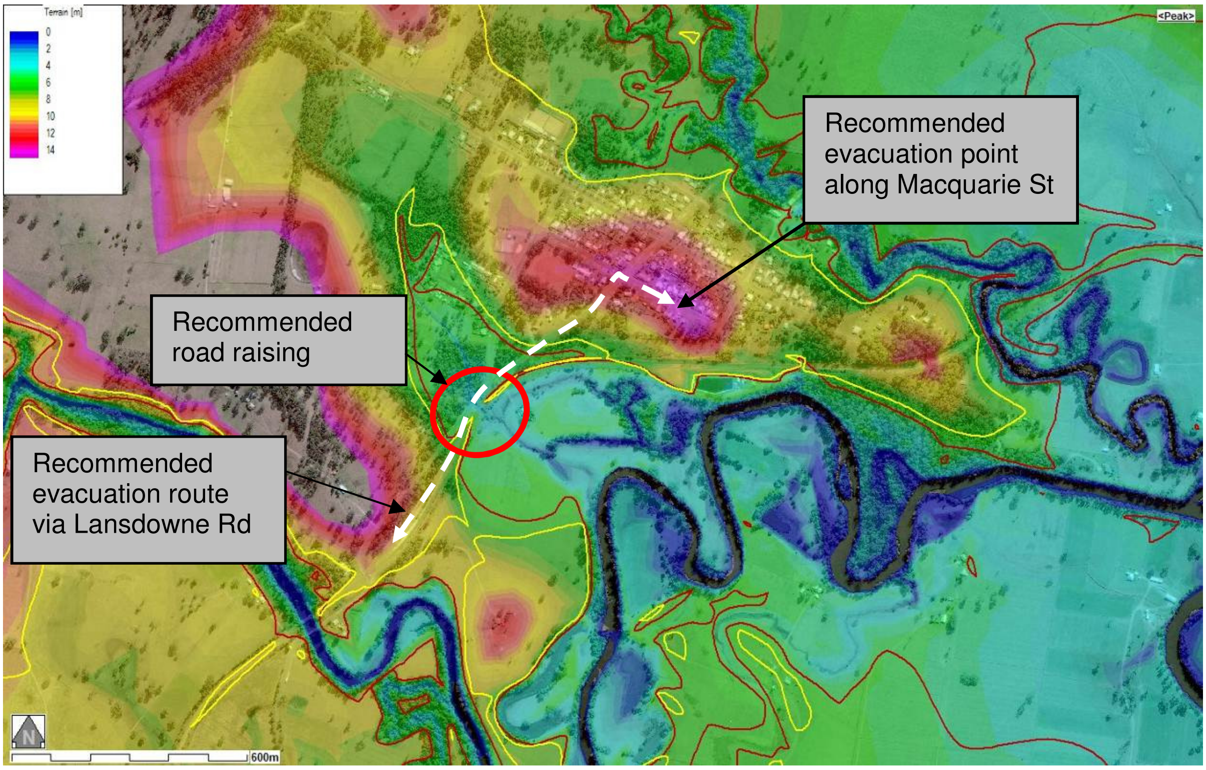

Figure 11: Location of flood access works required for evacuation, coloured by terrain elevation (m), showing the extents of the 1% AEP event in red and the PMF extents in yellow.

Figure 12: Location of proposed upgrade by raising the stretch of road along Cundle Road, Lansdowne

The intersection of Cundle Road, Yurong Street and Morrison Street is an integral access into Lansdowne Village. This part is isolated in the 1% AEP event and above.

To enable safe evacuation of occupants and to provide access into Lansdowne Village, raising of the section of the road is proposed. The proposed upgrade requires raising this stretch of the road and bridge (approximately 300 metres) by a height of 1 metre from the existing terrain (Figure 12). The recommended evacuation point is at the highest elevation in Lansdowne Village, at the midpoint of Macquarie St west of Cundle Road. The recommended evacuation route to this point is Cundle Rd, via Lansdowne Road. This route is detailed in Figure 11.

This low point on Cundle Road is also known to overtop during periods of high intensity rainfall on the local catchment and to impact on the low lying properties along Hampton Court. A flood study for the local catchment is recommended to assess the culvert requirements for Cundle road to minimise the potential for local stormwater flooding of Hampton Court.

5.2.2 Voluntary House Purchase (VHP)

In areas where Very High or Extreme hazards exist, there are little practical or economical options that can be employed to mitigate the risk to property and life. One option, that can be used in this case, is the Voluntary House Purchase (VHP) Scheme. It essentially removes the risk by ceasing the occupation of the Very High and Extreme hazard areas. This not only frees the residents of potential danger and cost, but also those in the rescue services who might otherwise be called upon during a flood.

VHP Eligibility and Conditions

The conditions for VHP are as follows:

1. A fair purchase price is offered; a valuation of the property is obtained from the NSW Valuer General *that ignores all flood hazards at the property*. Therefore the price offered is a fair price in line with the worth of the property to the owner.
2. It is completely voluntary; property owners are provided with their eligibility and have the option to continue living there or accepting the Council's offer to purchase their property.
3. Priorities given; if the number of people wanting to participate in VHP exceeds the annual budget allocated, properties will be prioritised based on the hazards outlined in VHP Eligibility, the age/health of occupants and the date of application.

Houses would be eligible based on the following requirements. They are either:

1. within an area where flood energy would lead to partial or complete destruction of the property where the property is in a *Very High* or *Extreme Hazard* according to 1% AEP event.
2. Within an area of *Very High* or *Extreme Hazard* for any flood risk up to the PMF and evacuation places the occupants or rescuers at an unacceptable risk to life. This would typically be because of an evacuation route:
   a. *descends*; which means that the occupants or rescuers would need to pass through a region subject to more severe hazards in order to evacuate.
      i. An example of this: A house is located at the end of a dead-end street next to a stream. The property and the street near the property are elevated at 15 metres. From the property over a distance of 40 metres, the street descends to 5 metres before going back up to 25 metres and connecting to another road another 50 metres away. In a large flood, the occupants need to evacuate their property because the hydraulic hazard is Very High and on-site refuge is not an option. Their only evacuation route is along their street. During this flood, the occupants remain at their property because they have seen many similar floods in the past that have not threatened their property, but only engulfed the lower surrounding land and road nearby. In this flood however, the water continues to rise, and it becomes clear to the occupants that they cannot remain at their property as it is becoming extremely dangerous. However at this stage, the highly hazardous floodwaters over the low surrounding land and their road make evacuation impossible.
   b. *Remains approximately level for a significant distance*; which means that the occupants or rescuers would need to travel a significant distance through a continuing level of

hazard that would increase with time. If this distance or the timeframe needed is unrealistic for safe wading and the location of the property is in a region where the rate of rise of floodwater is high, this would constitute an unacceptable risk to life.

i. An example of this: The same house is located at the end of a dead-end street next to a stream. The property and the street near the property are elevated at 15 metres. The street remains relatively constant in elevation for a kilometre before rising to connect to another road. During a large flood, the occupants need to evacuate; however in the time that it will take them to wade a kilometre, the hazards associated with the floodwater will be too high. Furthermore, although the occupants may know their street well, if it is night time, raining and covered in floodwater, it would be easy to wade slightly off track into deeper, more hazardous water.

As there are no properties that meet these requirements in the Lansdowne township area, VHP is assessed as not being applicable for flood risk management.

5.2.3 Development Controls and Zoning

Future development within areas of high risk to property or life should be permitted only for a particular flood compatible land use (for example, broad acre farming). This includes areas that are subject to areas defined as “high” hazards by the Floodplain Development Manual Preliminary Hazard Categories, as well as those areas where evacuation poses unacceptable risks for all flood risk up to the PMF. The FPL for the majority of properties located in Lansdowne village vary between 6.35 and 7.03m AHD (1% AEP plus 0.5 m freeboard). However site specific information should be obtained directly from the flood study results.

Future development within areas where risk to property and life can be managed should have controls implemented that ensure this is the case. These are associated with:

- **flood access**; to ensure that evacuation of the occupants can be reasonably undertaken
- **floor levels**; to ensure that tangible flood damage costs are reduced
- **impact on flood behaviour**; to ensure that levels and or velocities are not detrimentally increased in surrounding areas
- **construction type**; to ensure its stability during an extreme flood where on-site refuge is required

The Greater Taree DCP 2010 Part E, Flooding Requirements gives information on the use of flood prone land and its conditions according to the FPDM Hazard Categories. This is considered to adequately address the required Development Controls and Zoning in Lansdowne. FPDM Hazard maps are shown in Appendix A should be used in conjunction with the DCP 2010 in order to assess the controls and requirements of flood prone land in Lansdowne. The controls for flood prone land may require further review and updating in the DCP 2010 Part E, to incorporate areas identified as flood hazard risk by the supplied FPDM hazard maps. This also necessitates an update to GTCC’s Flood Planning Map in the LEP 2010 in conjunction with the flood mapping produced in this study.

The Lansdowne Community Survey, conducted by WorleyParsons and the Greater Taree City Council with the residents of Lansdowne, showed that Development Controls had an average support rating of 68% (amongst those who completed the survey).

5.2.4 Voluntary House Raising

Voluntary House Raising (VHR) has a long history in NSW with use in low hazard frequently flooded areas. The initiative involves the provision of Government financial assistance towards the cost of raising the property above the FPL.

This type of option is aimed at reducing the personal cost of flooding for properties that do not pose an unacceptable risk to life during flooding or through evacuation.

VHR Eligibility and Conditions

Houses affected by floodwater within the Council's FPL would be considered for VHR.

Of these properties, those houses physically eligible for VHR must be:

a) Constructed of the right materials; houses of single or double brick construction or slab-on-ground construction are generally either impossible or too expensive for VHR. Houses made of timber-frames and clad with non-masonry materials are best suited and are the only ones considered eligible for VHR in this study.

b) Within a low, medium or high hazard zone; houses within a *Very High* or *Extreme* hazard zone can be destroyed by floodwater and raising the property does not remove this risk. Those properties that are in a *Very High* or *Extreme* zone for the 1% AEP are not considered. Furthermore, evacuation difficulties, summarised in the previous section (Voluntary House Purchase, VHP Eligibility; Point 2. a. and b.) are also relevant considerations when ascertaining the eligibility of a property for VHR.

Based on the aforementioned criteria, there are no properties affected by over floor flooding in the 1% AEP in Lansdowne Village that would be eligible for VHR, mainly due to the fact that the affected houses are typically slab-on-ground construction.

The Lansdowne Community Survey, conducted by WorleyParsons and the Greater Taree City Council with the residents of Lansdowne, showed that less than 20% (amongst those who completed the survey) are in support of VHR.

5.3 Response Modification

The following Response Modification options were considered for Lansdowne:

1. Flood Predication and Warning

2. Flood Education and Community Awareness
3. Local Flood Planning

5.3.1 Flood Prediction and Warning

Currently, there is only one (1) river gauge on the Lansdowne River (located several kilometres upstream of Lansdowne village) which is monitored by the Taree City SES through the correlation of readings and historic data. A flood level of 7.0m AHD was selected as a "significant" at the Lansdowne gauge.

The SES are also typically provided with confidential, predicted flood information from the Bureau of Meteorology (BoM) using simulated systems based on rainfall in the catchment. These complement the BoM's flood warnings based on river readings that are publicly provided.

These sources of information allow the SES to apply their community evacuation plan when required with its effectiveness based on the accuracy of the information and the warning time provided. It is understood that the current system allows between three to four hours warning time before major flooding occurs in Lansdowne.

In order to increase this warning time, more river and rainfall gauges could be installed in the catchment, the number and placement thereof subject to further study. There are currently no rainfall catchment gauges within the Lansdowne Catchment and the nearest rainfall gauge is situated at Taree, nearly 15km to the south. The addition of a rainfall gauge in the upper catchment would enable the BOM and SES to optimise the response time of the catchment and provide more reliable and timely warnings. The BOM and SES should be consulted further to confirm the cost – benefit value of such additional data on their current forecast procedures. Further discussion with the community regarding such a system's value would be required.

The Lansdowne Community Survey showed that improvements and support for flood prediction and warning systems had an average support rating of less than 60% (amongst those who completed the survey).

5.3.2 SES Local Flood Planning

The flood affected properties were grouped by hazard category and evacuation needs during an extreme flood (Section 5.1).

Whilst the SES is responsible for preparing and implementing flood evacuation plans, Council must ensure that evacuation routes are accessible and consideration is given to works that could alleviate the burden on the SES (Section 5.2.1). Currently, there are no areas in Lansdowne identified as essential where improvements could be undertaken.

The requirements of each area in Lansdowne that has a specialist evacuation need should form part of the education and community awareness program (Section 5.3.3). Many inundated areas in

Lansdowne have a sufficient time for self or assisted evacuation. After this time elapses, evacuation becomes rapidly hazardous to life, and support relies on rescue missions which may place SES personnel's lives at risk.

Such planning will ensure that in areas where self and assisted evacuation are identified, the residents are informed and that potential problems such as loss of evacuation routes or unwillingness of residents evacuate in critical areas of the floodplain, are accounted for.

Furthermore, flood recovery plans should be developed to ensure that the efforts can be readily implemented, especially for more extreme flooding when Lansdowne as a whole may be cut off from other communities.

Currently, a draft Local Flood Plan (LFP) for the Greater Taree area is available for public exhibition. This LFP covers the emergency response during a flood event for the township of Lansdowne and the surrounding areas. Design flood data and flood hazards mapping from the Lansdowne Flood study and the Lansdowne Flood Risk Management Study should be incorporated into the LFP to help SES target vulnerable areas and create appropriate emergency response measures.

The Lansdowne Community Survey showed that improvements and support for flood education and readiness had an average support rating of 60% (amongst those who completed the survey).

5.3.3 Flood Education and Community Awareness

Educating the local community forms the mechanism by which Flood Prediction and Warning as well as Local Flooding Planning are introduced to the community. A flood educated community will inherently have a lower cost associated with flooding because property damage and evacuation risks can be minimised for both the community members and rescue workers.

Flood education needs to be an ongoing and repetitive component of a flood warning system to ensure flood awareness is maintained in a community. Flood awareness is dependent on a person/ community's exposure to previous floods; the frequency and impacts of such exposure; and the duration which they have lived in that residence or area. Information delivered as a "one off" or by one form of media only is not an effective means to ensure a community maintains adequate knowledge of their flood risk.

Flood Education and Community Awareness should be divided into several categories:

- Education about Flood Risk

  Flood risk tends to mislead or be misinterpreted by people and this should be confronted in the education program.

  Sustaining the appropriate level of flood readiness is not easy and scepticism is understandable in the absence of large floods. Historic flood information should be provided on similar catchments and flood patterns.

- Education about flood warning, the SES role and what can be expected during flooding

  This allows people to have a general plan when flood warnings are issued and understand the meaning of the warnings, potentially reducing the personal costs of flooding.

- Specific information about evacuation

This allows the SES and other rescue workers to focus on evacuation rather than rescue if residents do not evacuate when required, reducing the risk to life that exists. The reasons for evacuation, the procedures, the route and destination of evacuation should be understood.

All information can be provided or distributed to the community via the media, special brochures, school education, physical apparatus (such as flood markers) and community noticeboards (within shopping centres, public areas, etc.)

As the Floodplain Development Manual states, "the cost of such efforts should be regarded as the maintenance for a flood warning and evacuation scheme".

The Lansdowne Community Survey showed that improvements and support for flood education and readiness had an average support rating of 60% (amongst those who completed the survey).

5.4 Flood Modification

Flood modification measures are aimed at modifying the behaviour of the flood itself, by reducing levels or velocities or through the exclusion of floodwaters. These mechanisms may require significant capital works to gain a benefit and may be suited only for certain scenarios.

During design flood simulation, Cross Creek has shown that although it does not govern the ultimate peak flood level experienced in Lansdowne, it leads to rapid inundation of a few properties in North Lansdowne, prior to levels in the Lansdowne River becoming influential. This leads to properties which are subject to rapid (peak inundation within 2 hours with a peak rate of rise of 1.2 metres per hour) riverine flooding from Cross Creek, leading to a higher amount of property damage because residents have little if any warning time to prepare.

Design flood simulation of Lansdowne River has also shown that the intersection of Cundle Road, Yurong Street and Morrison Street, which provides an integral access route, is inundated and therefore access is restricted to and from Lansdowne Village.

The following Flood Modification options were considered for Lansdowne:

1. Cross Creek Levee
2. Lansdowne Flood Retardation Basins

5.4.1 Cross Creek Levee

The proposed Cross Creek Levee aims to reduce the impact of flooding by preventing flow from Cross Creek entering properties along Croki Street, North Lansdowne for flood events with a recurrence interval up to 100 years (1% AEP) plus freeboard of 500m.

This flood modification measure deals with peak flood levels at Cross Creek.

In order to be effective and preclude floodwaters from entering Lansdowne Village from the north, it must be fully enclosed along the vulnerable sections with high terrain as shown in Figure 13. A cross-sectional profile of the terrain along the track of the proposed levee is provided in Figure 14.

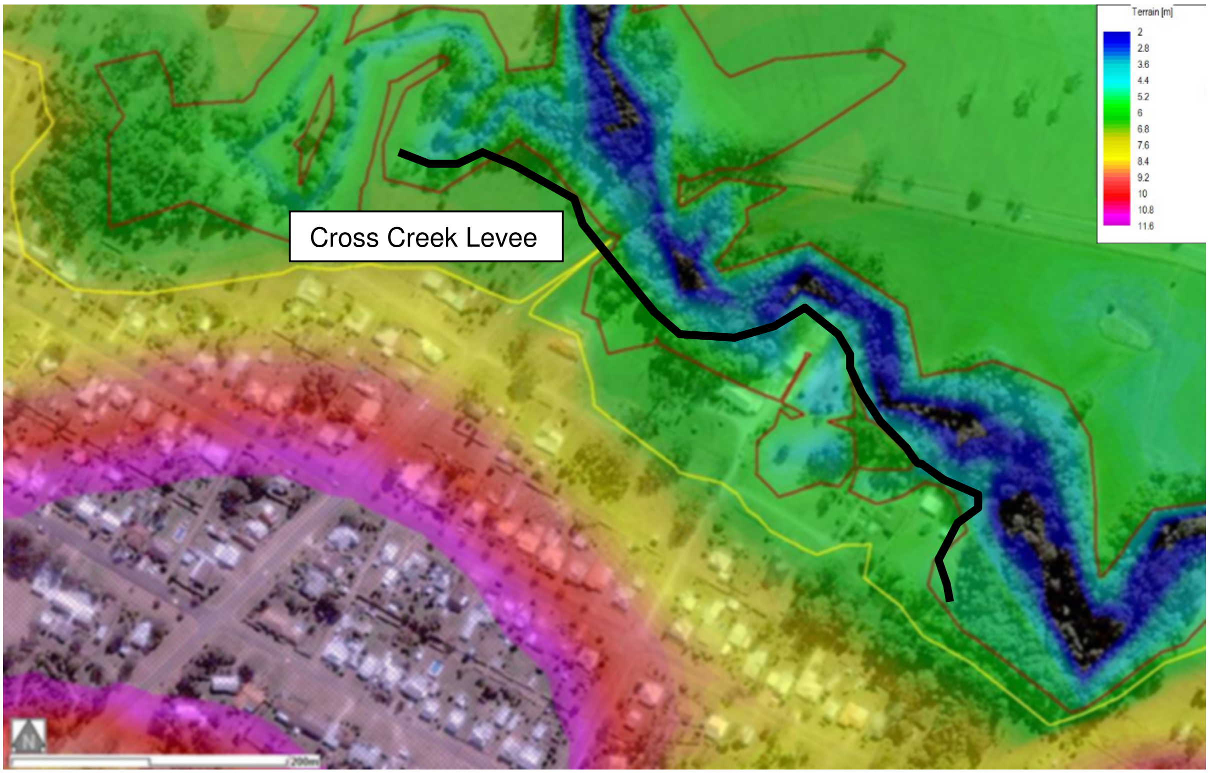

Figure 13: Proposed Cross Creek Levee (in yellow); with elevation coloured, showing the extents of the 1% AEP event in red and the PMF event in yellow.

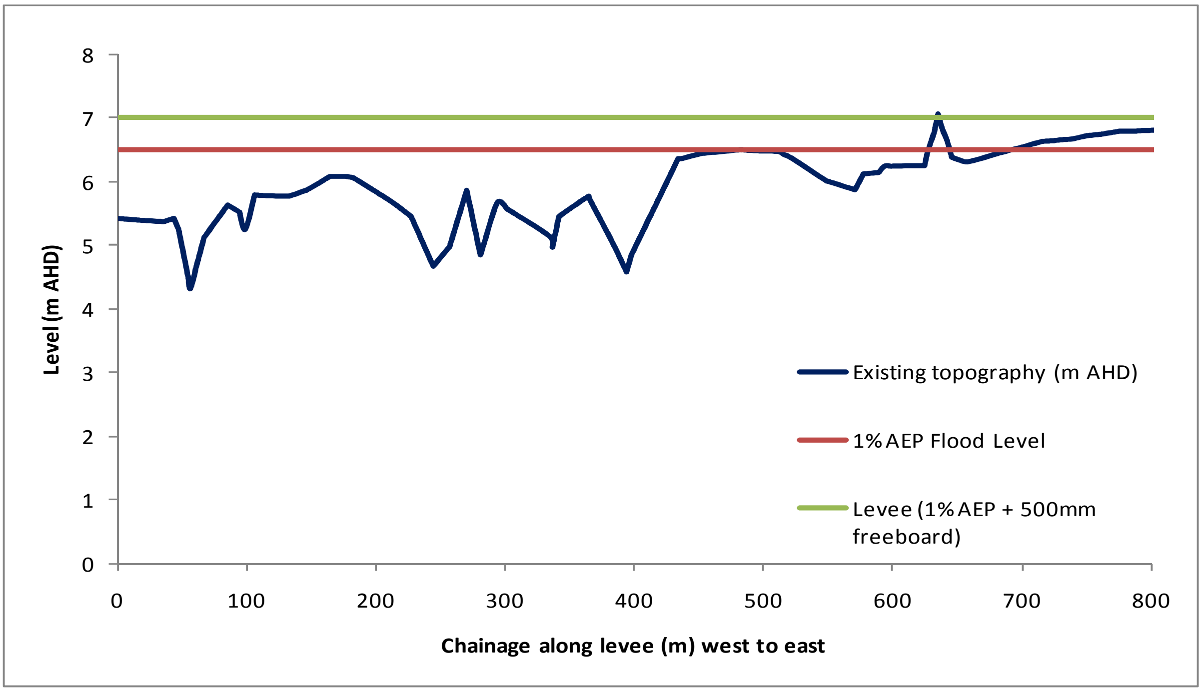

Figure 14: Cross-sectional view of the proposed Cross Creek Levee

The proposed details of the levee are as follows:

- The levee is aimed at preventing floodwaters with an AEP of less than 1% (plus a freeboard of 500mm) from entering the areas along Croki Street at North Lansdowne.
- The proposed permanent earth embankment with an average height of 1.1 metres from an average ground height of 5.9 metres and a crest width of 1500mm with a 1V:2H slope, spanning approximately 800 metres, primarily following the south side of Cross Creek.
- The total cost of the Cross Creek Levee, using the aforementioned design criteria is approximately $858,000. This was estimated based on the following cost guide, derived from Rawlinson's, 2008:
  - Site preparations, excavation, clearing of vegetation and minor road works at $64 per m^3 = $208,000
  - Construction of earth embankment along 800 metres, with a height that varies according to the profile provided in Figure 14 at $200 per m^3 = $650,000

Table 3 shows a revised AAD and PV cost of flooding in Lansdowne over the next 50 years considering the benefits of having the proposed levee against a do-nothing approach. It should be noted that the damaged are estimated considering only residential properties.

Table 3: Average Annual Damages and Present Value over 50 years for Lansdowne in 2014 dollars, considering the construction of the Cross Creek Levee over 50 years period[3]

	AAD	PV (7%)
Damages with construction of Cross Creek Levee	$445,200	$6.143 M
Benefit compared to existing	$129	$2,130
Benefit to Cost Ratio	0.002	

The benefit to cost ratio of less than 0.1 showed that the construction of the proposed levee represents a high cost with no substantial benefit provided over the existing condition.

[3] It must also be remembered that only a selected number of houses were used in these calculations. This number represents all houses within the fringe of the 1% AEP flood extents and therefore the cost of flooding for events in excess of the 1% AEP will likely have greater costs. This however does provide a good indication for measuring the benefit of floodplain risk management strategies as the Council's FPL is in line with the 1% AEP.

5.4.2 Lansdowne Flood Retardation Basins

An option to manage excess stormwater runoff during a flood is the use of flood retardation basins which make use of the existing geomorphology with some modifications. These basins store runoff to reduce downstream flood levels and minimise flood damage.

To have a significant effect, a basin needs to have a large enough volume to accommodate an effective proportion of the target flow hydrograph. The Hampton Court area would benefit the most from reduced flood levels, especially at the 1% AEP flood. The flow volume inherent in reducing the peak 1% AEP level to that of the 2% AEP is approximately 2 million m^3. With basin depths being limited by the depth of the channel relative to the adjacent floodplain levels, such a volume would require a large area.

There is limited scope across the floodplain upstream of the tidal limit for such an area. However, directly opposite the Hampton Court area, the channel passes through a series of tortuous meanders where the encompassing floodplain is low, contains several ponds and is likely to be marginal land.

Although this area is not large enough to create a basin of 2 million m^3, a reasonable basin layout was examined to see what benefits could be derived.

A potential basin, as shown in Figure 15, adjacent to the property 1344 Lansdowne Road, was investigated as a means of reducing flooding at the intersection of Cundle Road, Yurong Street and Morrison Street.

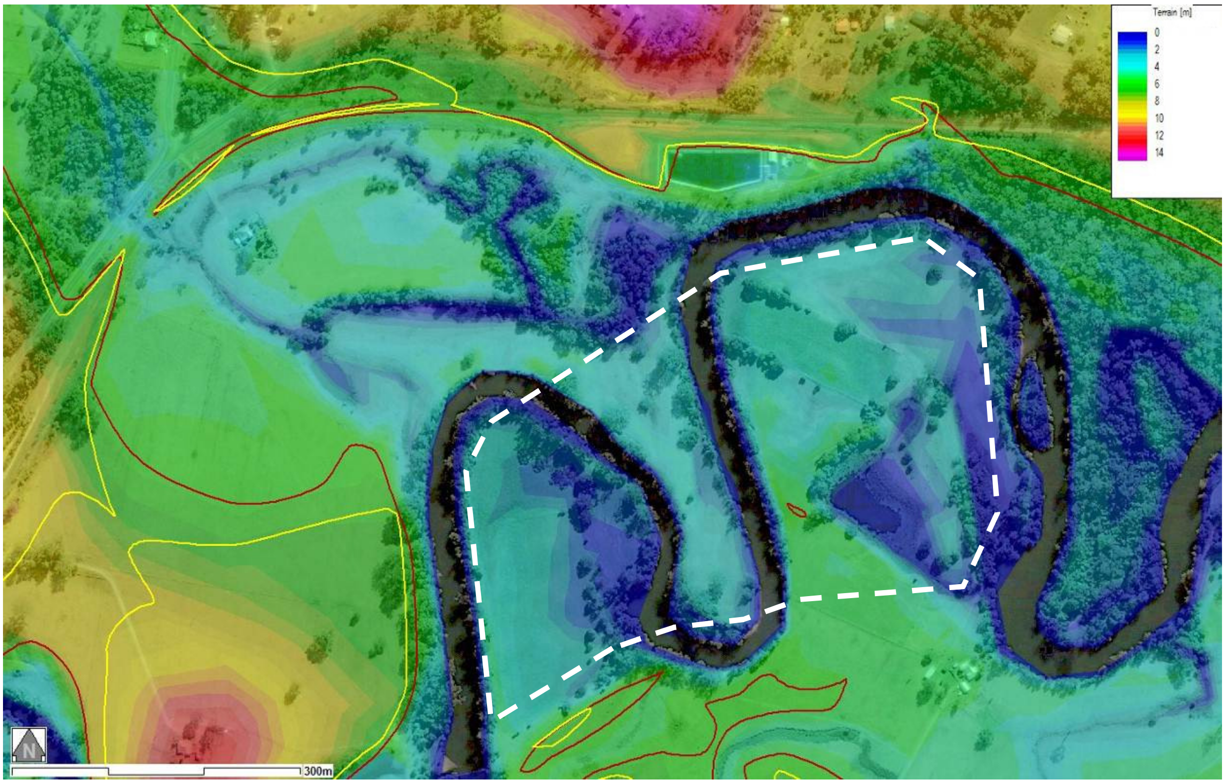

Figure 15: Location of suggested Lansdowne Flood Retardation Basins (dotted line in white), coloured by terrain elevation (m). The extents of the 1% AEP and PMF events are shown in red and yellow respectively.

The storage capacity of the retardation basin is partially limited by the geomorphology of the site which has a maximum area of approximately 200,000m^2. In order to maximise storage volume, the site would have to be excavated to an average depth of 4.5m. The excavation costs alone for the flood basin would be in the range of $12 million. This cost is based on $20 per m^3 for removal and disposal of material, without considering further costs associated with drainage, flow paths and structural works.

To provide a measurable benefit, the retardation basin should be able to reduce the peak level of the 1% AEP by a significant amount, e.g. reducing the 1% AEP peak flood to a 2% or 5% AEP level. Table 4 summarises the effectiveness of the peak water level at the proposed retardation basin for different flood events.

Table 4: Retardation basin effectiveness

	Peak reduction upstream
1% AEP Flood	0.05m
2% AEP Flood	0.06m
5% AEP Flood	0.09m

The effectiveness of the potential retardation basin indicates a reduction of 0.05m for the 1% AEP flood (Table 4). Slight improvements are indicated for the lesser 2% and 5% AEP floods, but likewise there are less affected properties for these floods.

In contrast, reducing the 1% AEP peak flood level to a 2% equivalent level would require a reduction of 0.23m. This is significantly more than the indicated effectiveness of the potential basins and given the high costs, further consideration of retardation basin as a mitigation measure is not warranted.

6. FLOOD STANDARD AND CONSIDERATIONS

The selection of an appropriate flood standard is an integral step in the development of a floodplain management plan as the Floodplain Development Manual clearly states. The current General Flood Planning Level (FPL) employed by the Greater Taree City Council is based on the 1% AEP plus a 500 mm freeboard.

This is considered to be a sound basis for planning in Lansdowne because

- it is recommended by the Floodplain Development Manual (FPDM)
- it is widely understood and used throughout Australia
- it has been in use since the Council's *Interim Flood Policy* was introduced in 1987
- it was recommended by the *Manning River Floodplain Management Study* in 1996
- it is used in the Greater Taree Development Control Plan (DCP) 2010
- a higher standard would increase mitigation costs to the community and Council
- a lower standard would expose residents to unacceptable risk of which the costs would potentially be borne by the wider community

The current FPL using the 1% AEP event plus a 500 mm freeboard is recommended to be maintained and is used as a basis for developing management strategies in this study.

From the Flood Study results, the level of the 1% AEP event through the majority of Lansdowne is between 5.85 to 6.53m AHD. Therefore the FPL will vary between 6.35 and 7.03m AHD for the majority of properties located in Lansdowne village (although the flood study results should be consulted for site-specific levels).

7. REFERENCES

1. WorleyParsons; “Lansdowne Flood Study: Review, Upgrade and Extension” ; June 2011
2. Public Works Department, NSW; “Manning River Flood History 1831-1979”; October 1981
3. Department of Infrastructure, Planning and Natural Resources, NSW; “Floodplain Development Manual”; April 1995
4. Greater Taree City Council, Willing & Partners, ERM Mitchell & McCotter, WBM Oceanics; “Draft Manning River Floodplain Management Study”, Volume 1 and Volume 2; May 1996
5. Greater Taree City Council and State Emergency Service, “Greater Taree City Local Flood Plan: A sub-plan of the Greater Taree City Local Disaster Plan (Displan)”; August 2007.
6. Greater Taree City Council; “Disaster Control Plan (DCP)”; 2010.
7. McConnell and Low; “New Directions in Defining Flood Hazard and Development Control Planning”; 2001

APPENDIX A – FLOOD PLANNING LEVEL MAP

This section provides a summary of important level maps from the Lansdowne Flood Study, 2011.

Figure A1 shows the 1% AEP design flood levels in the Lansdowne study area while Figure A2 shows the FPL (that is, the 1% AEP level plus a 0.5 metre freeboard) of the same region. Both figures show levels in 0.5 metre increments.

The extent of flood prone land is shown as a red outline (the extent of the PMF).

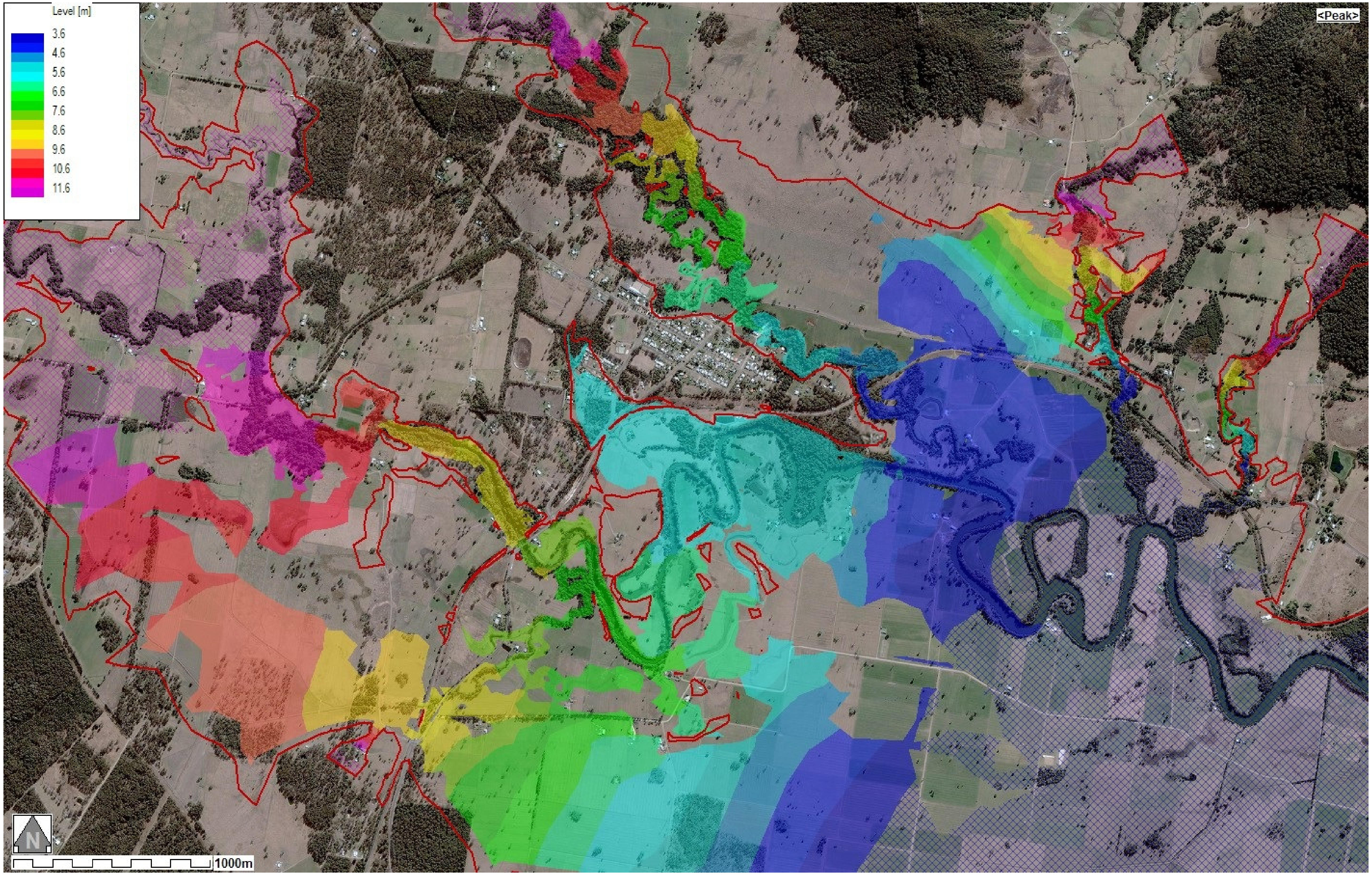

Figure A1: 1% AEP Design Flood Level in Lansdowne showing 0.5 m contours. The extent of flood prone land is shown as a red outline (extent of the PMF).

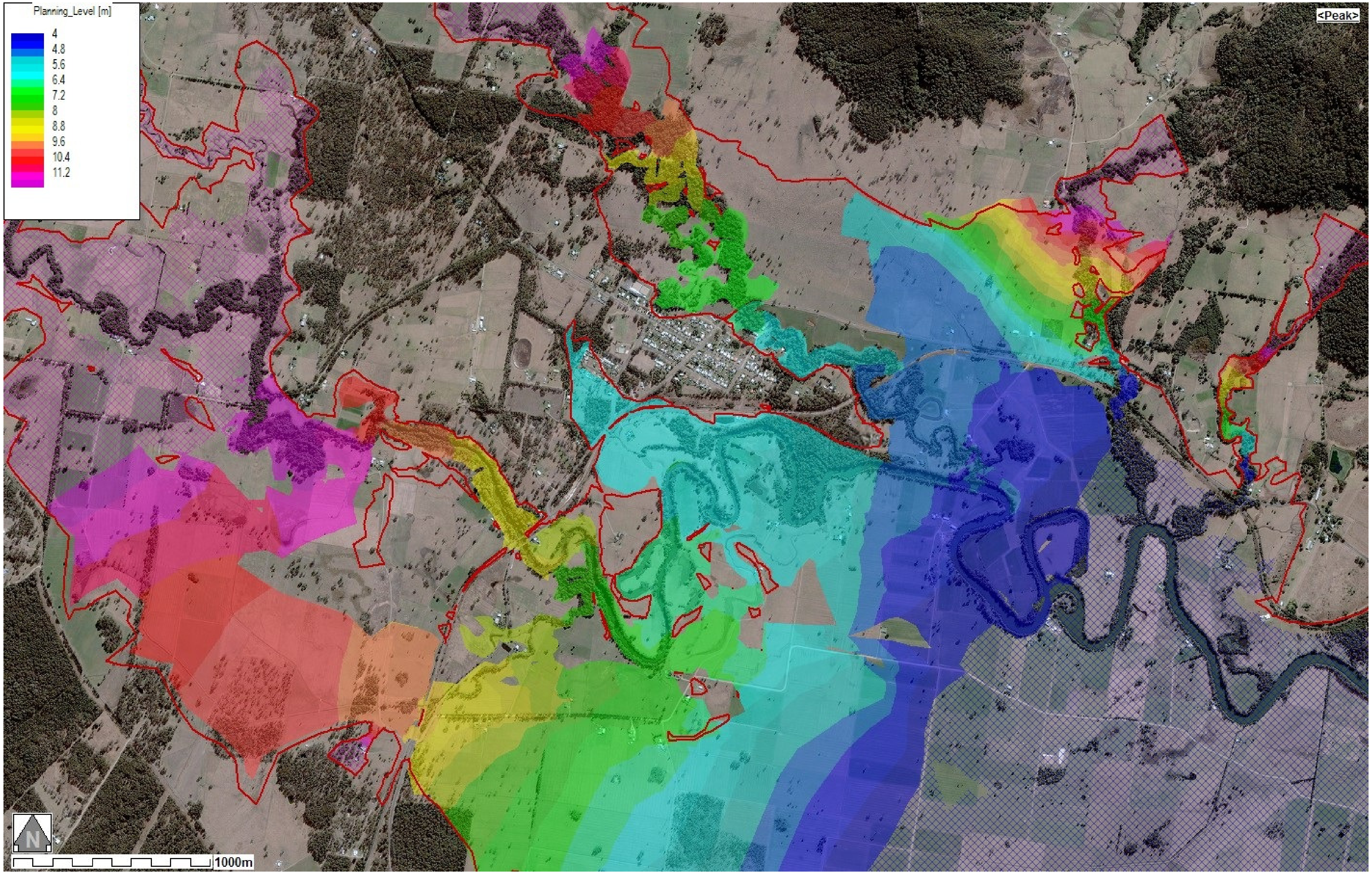

Figure A2: The Flood Planning Level in Lansdowne (using the 1% AEP Design Flood Level plus 0.5 m freeboard); showing 0.5 m contours. The extent of flood prone land is shown as a red outline (extent of the PMF).

APPENDIX B – FLOOD HAZARDS MAPS

An expanded approach to assessing the combined risk to property and life is the hydraulic hazard categorisation scheme discussed in *"New Directions in Defining Flood Hazard and Development Control Planning"; McConnell and Low, 2001*. The objective of this method is to facilitate cadastral based flood hazard classifications and associated criteria to assist in strategies to achieve equitable management of floodplains. This method is based on quantities derived from the Flood Study and therefore there is little, if any, difficulty or subjectivity in defining the hydraulic hazards. In comparison with the FPDM hazard categories, the expanded approach allows for Floodplain Managers to better address the varying risks associated with rarer floods above the Flood Planning Level (Figure B1).

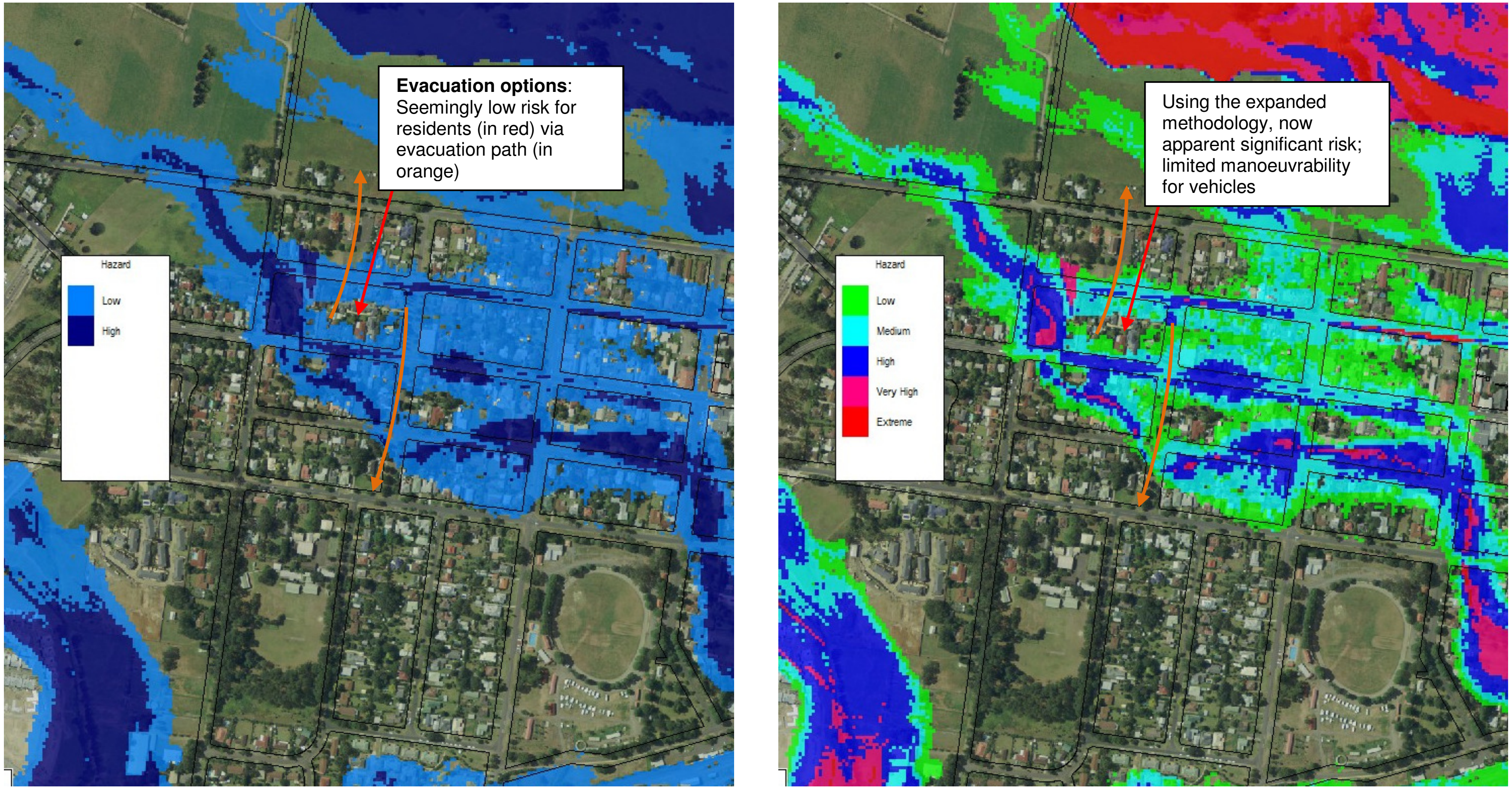

Figure B1: Comparison of Hazards mapping for a PMF flood event, showing (left) FMM hazards and (right) expanded hazards

The hydraulic hazard structure and methodology used to assess risk to property and prepare the maps in Appendix B are based on the following categorisation scheme (using the 1% AEP event):

- **Low Hazard**; depth < 0.4 m and velocity < 0.5 m/s
  - Limit for the stability of cars
- **Medium Hazard**; depth < 0.8 m, velocity < 2 m/s and velocity times depth < 0.5 m^2/s
  - Limit for the stability of heavy vehicles
  - Safe wading of able-bodied adults
- **High Hazard**; depth < 1.8 m, velocity < 3 m/s and velocity times depth < 1.5 m^2/s
  - Limit for the stability of light framed construction (timber frame, brick veneer, etc.)
- **Very High Hazard**; velocity > 0.5 m/s and < 4m/s and velocity times depth < 2.5 m^2/s
  - Limit for the stability of heavy framed construction (steel frame, etc.)
- **Extreme Hazard**; velocity times depth > 2.5 m^2/s with a minimum velocity of 0.5 m/s
  - Development considered unsuitable and likely to adversely impact flood levels

The following diagram shows the base flood hazard categorisation used:

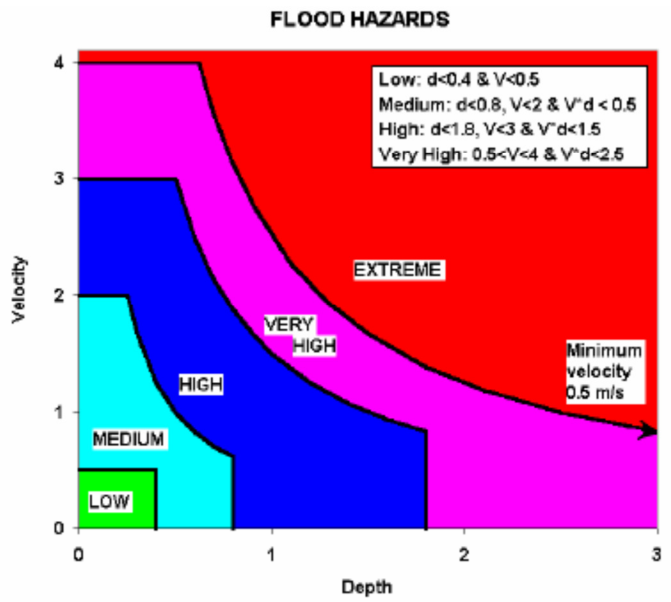

Figure B2: Expanded preliminary hydraulic hazards used in this study

These hydraulic hazard categories essentially measure the amount of energy associated with a location for a given flood. This method is based on quantities derived from the Flood Study and therefore there is little, if any, subjectivity in defining these. Hydraulic hazard maps for Lansdowne using this expanded scheme are shown in Figures B3 to B7 for the 5%, 2%, 1% & 0.5% AEP and PMF design floods respectively. Provisional hazard maps based on the FPDM categories are shown in Figures B8 to B11 for the 5%, 2%, 1%AEP and PMF design floods.

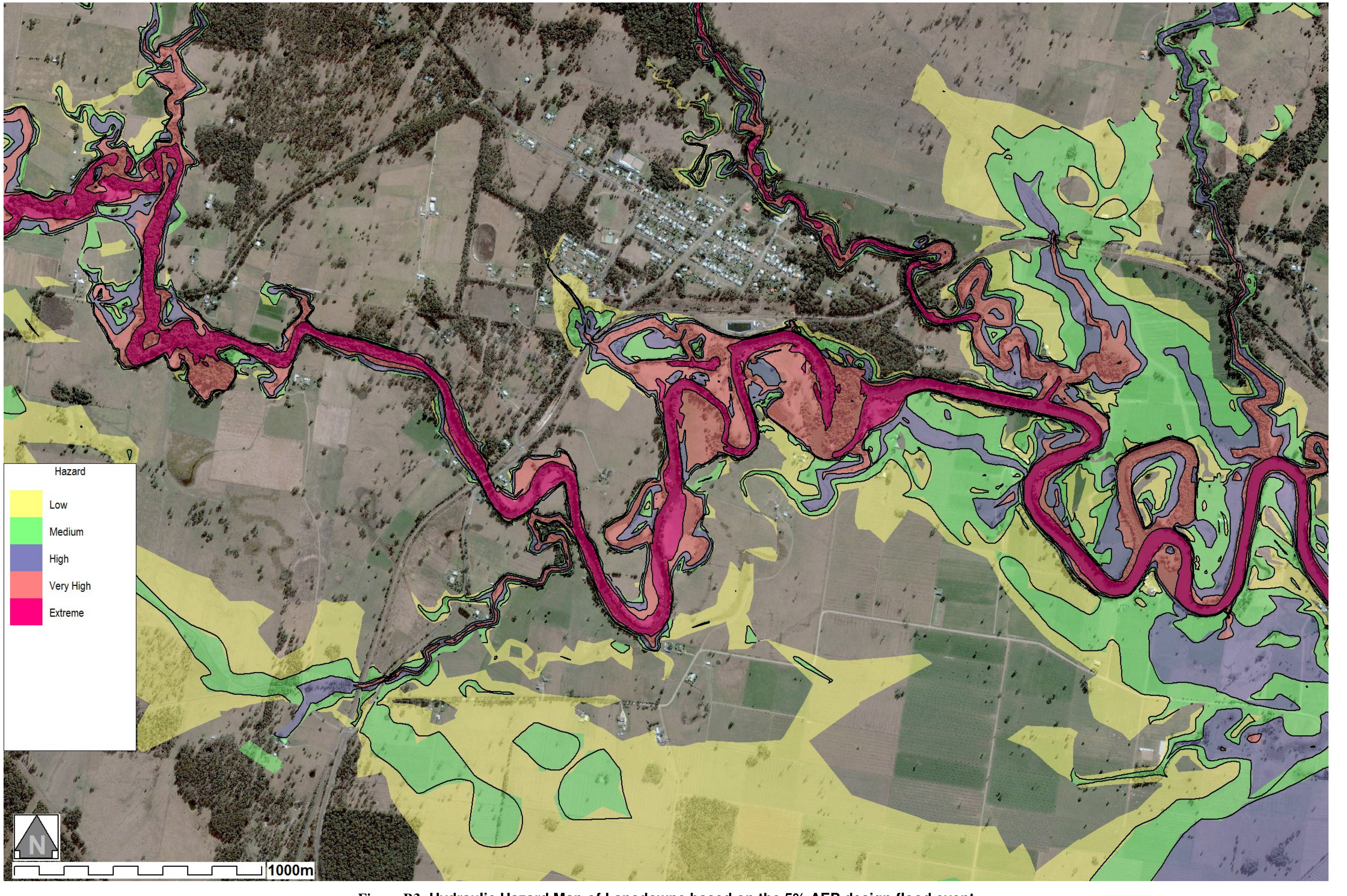

Figure B3: Hydraulic Hazard Map of Lansdowne based on the 5% AEP design flood event

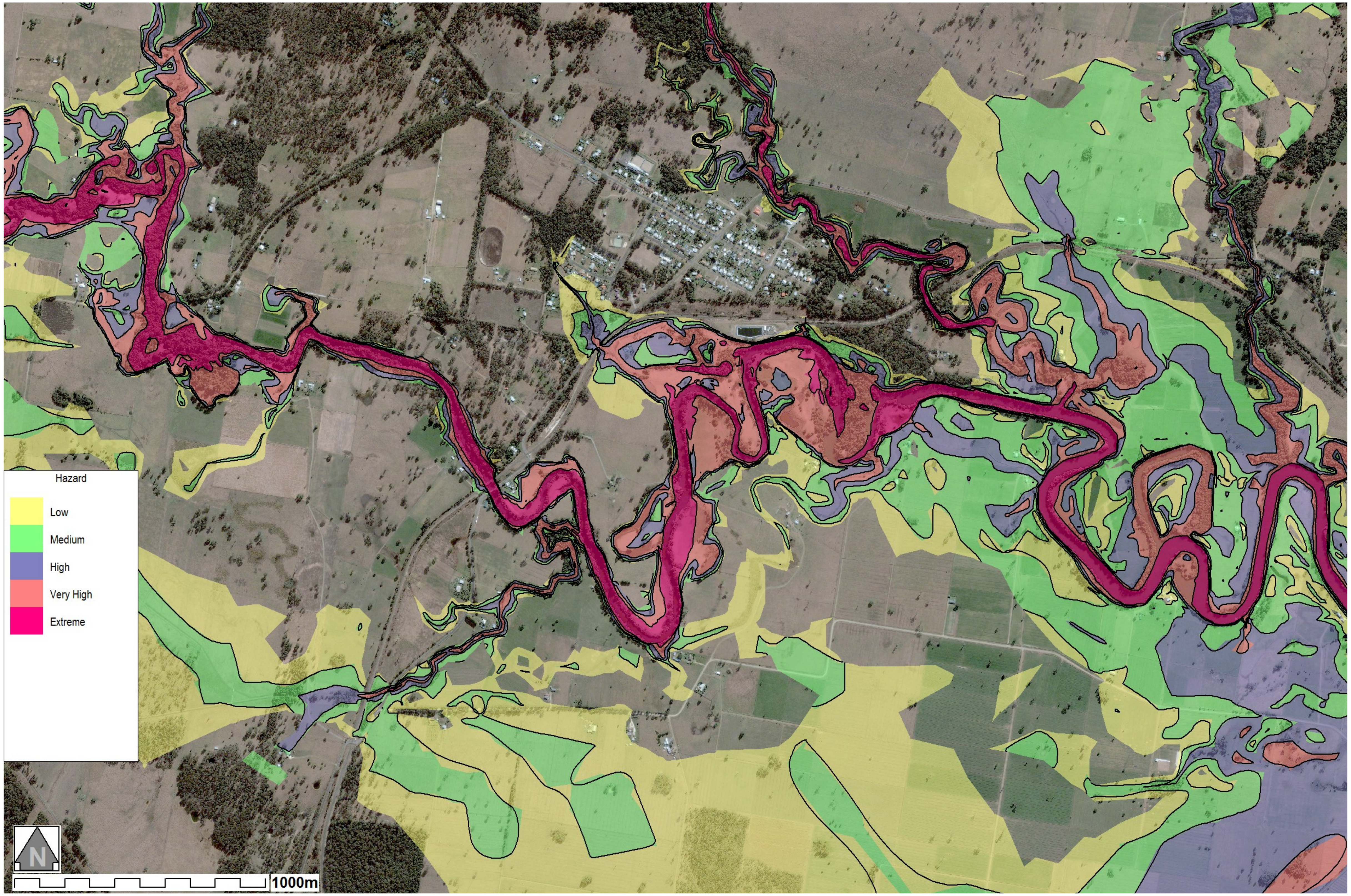

Figure B4: Hydraulic Hazard Map of Lansdowne based on the 2% AEP design flood event

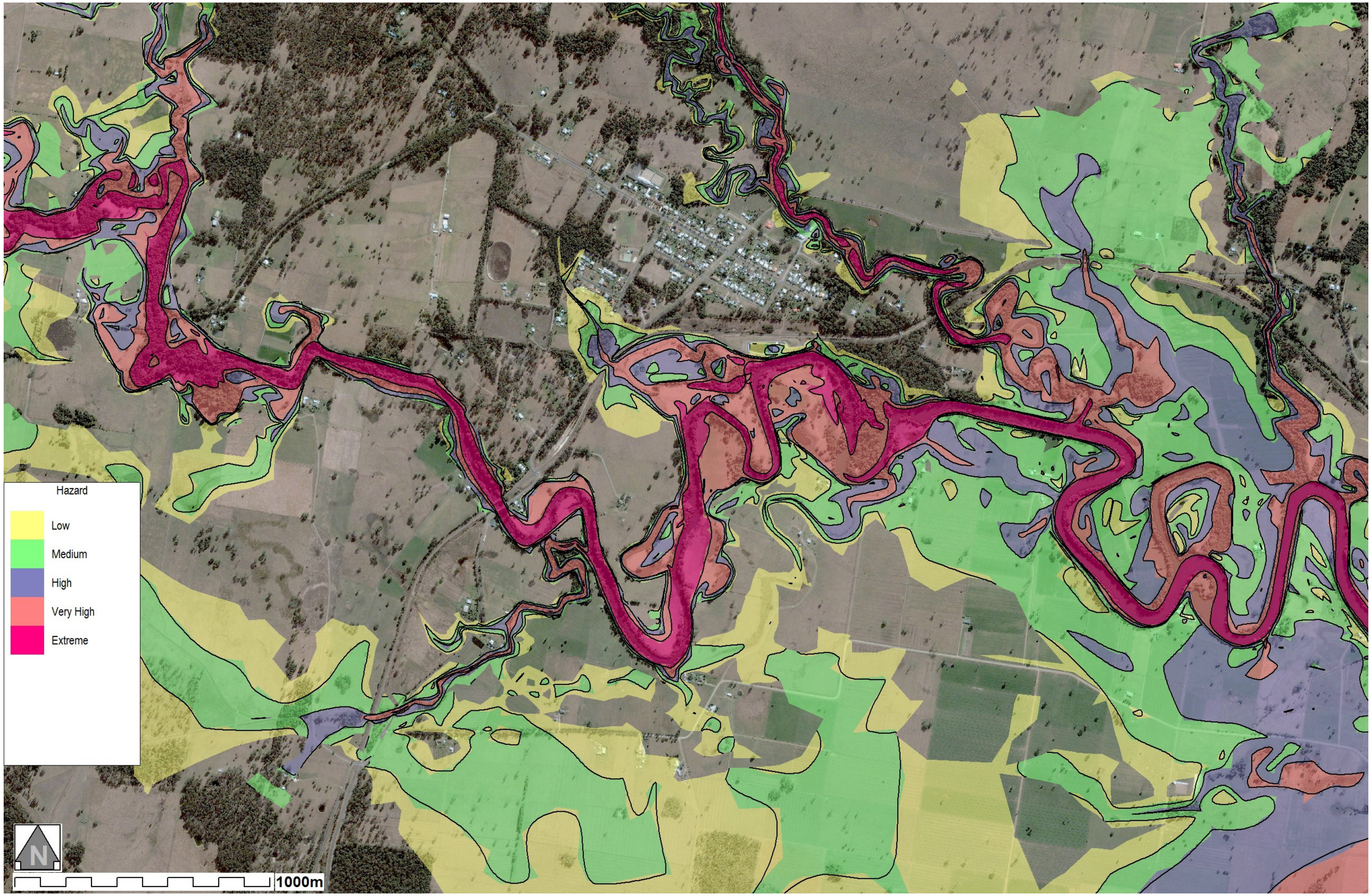

Figure B5: Hydraulic Hazard Map of Lansdowne based on the 1% AEP design flood event

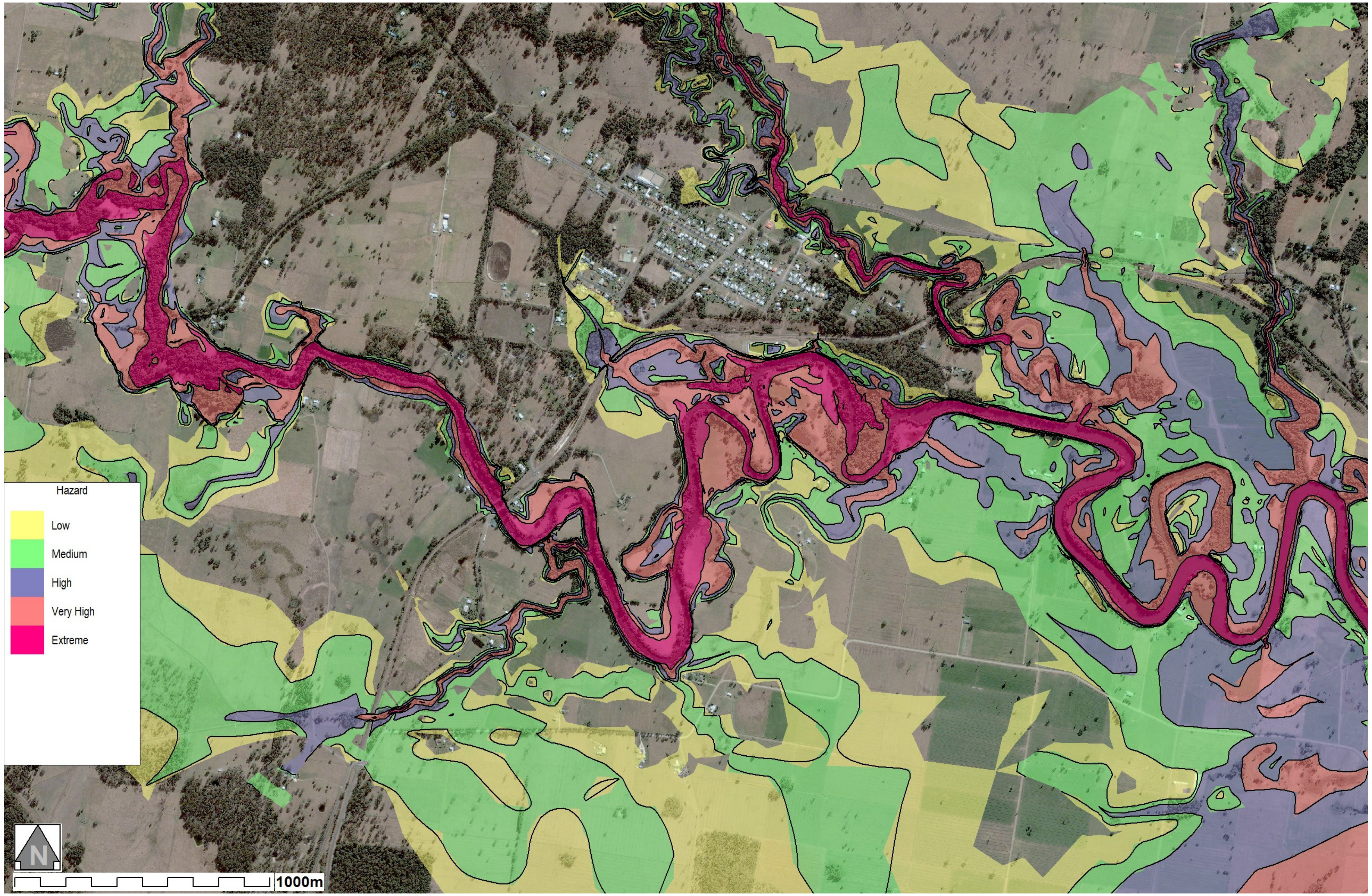

Figure B6: Hydraulic Hazard Map of Lansdowne based on the 0.5% AEP design flood event

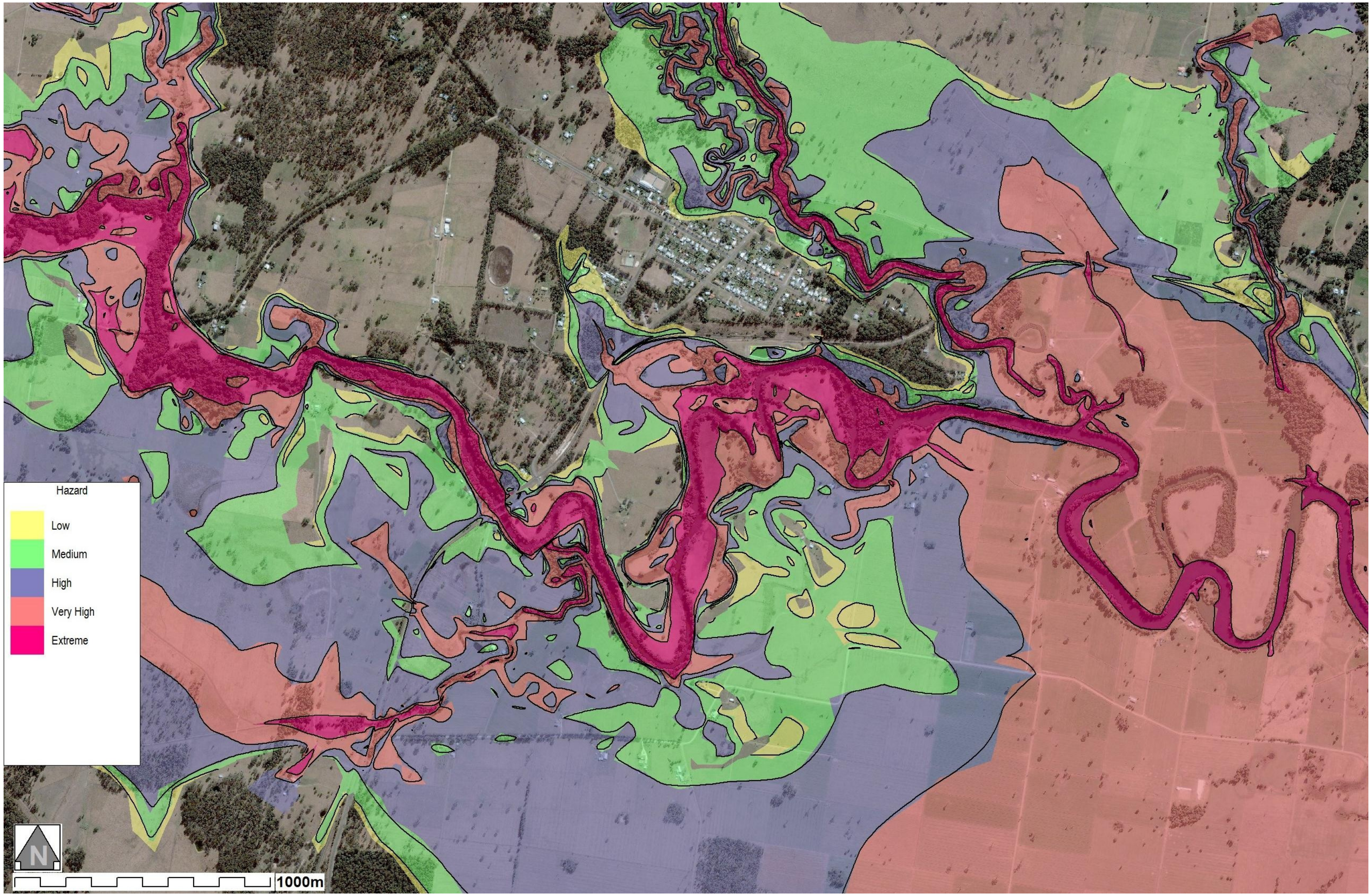

Figure B7: Hydraulic Hazard Map of Lansdowne based on the PMF flood event

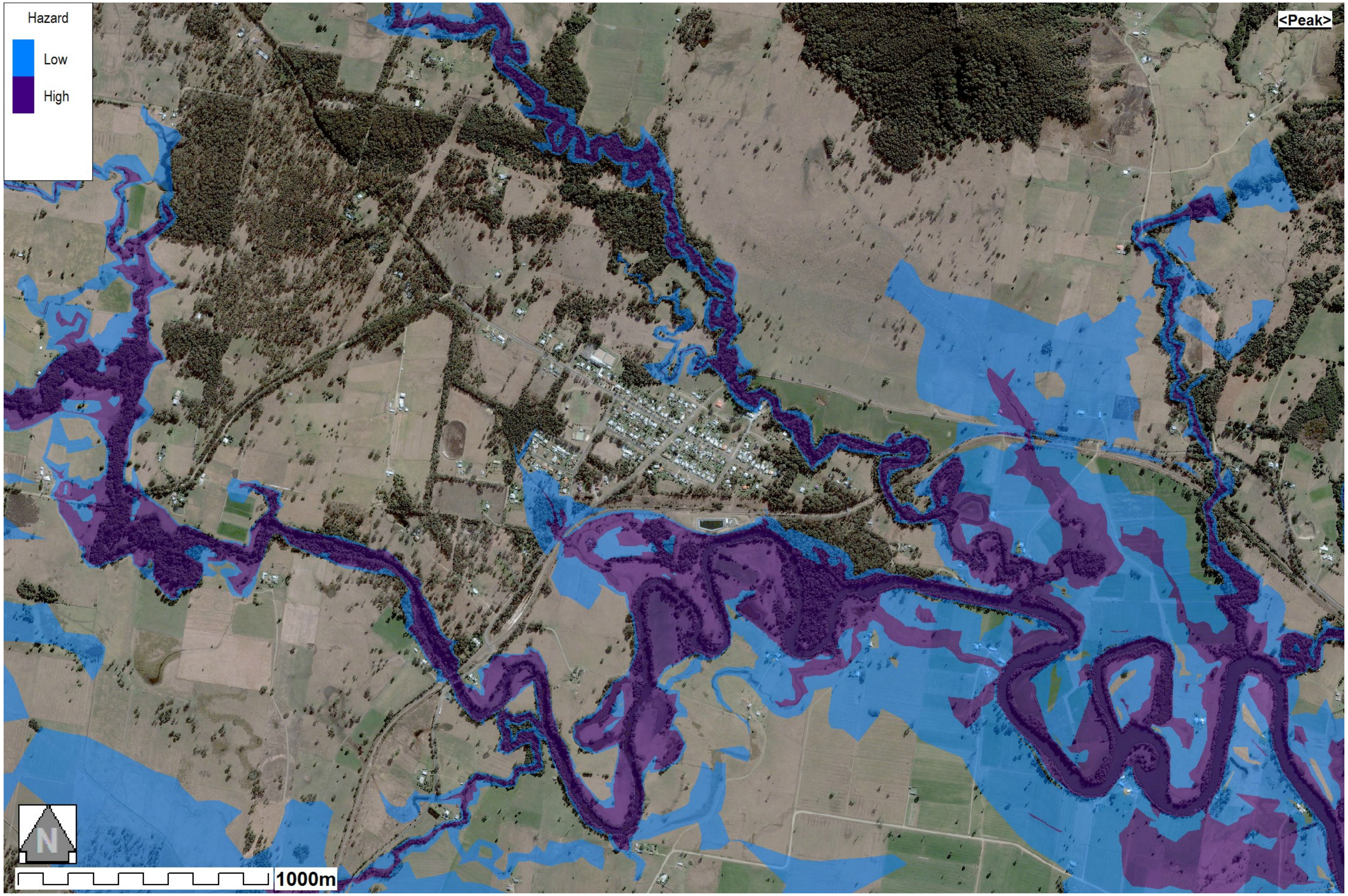

Figure B8 : Provisional Hazard Map for the 5% AEP flood event, based on the requirements of the FPDM and GTCC LEP/D

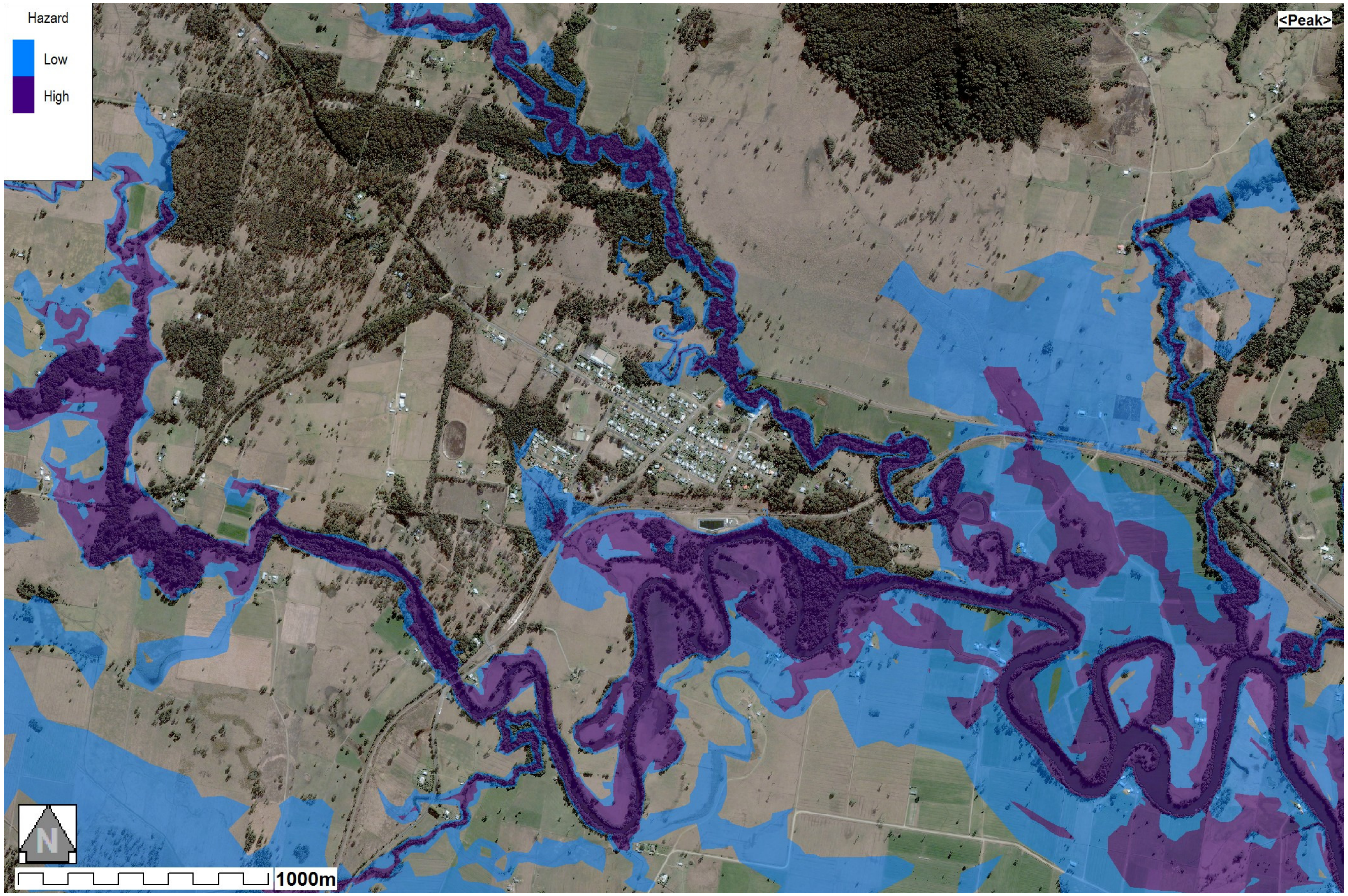

Figure B9 : Provisional Hazard Map for the 2% AEP flood event, based on the requirements of the FPDM and GTCC LEP/D

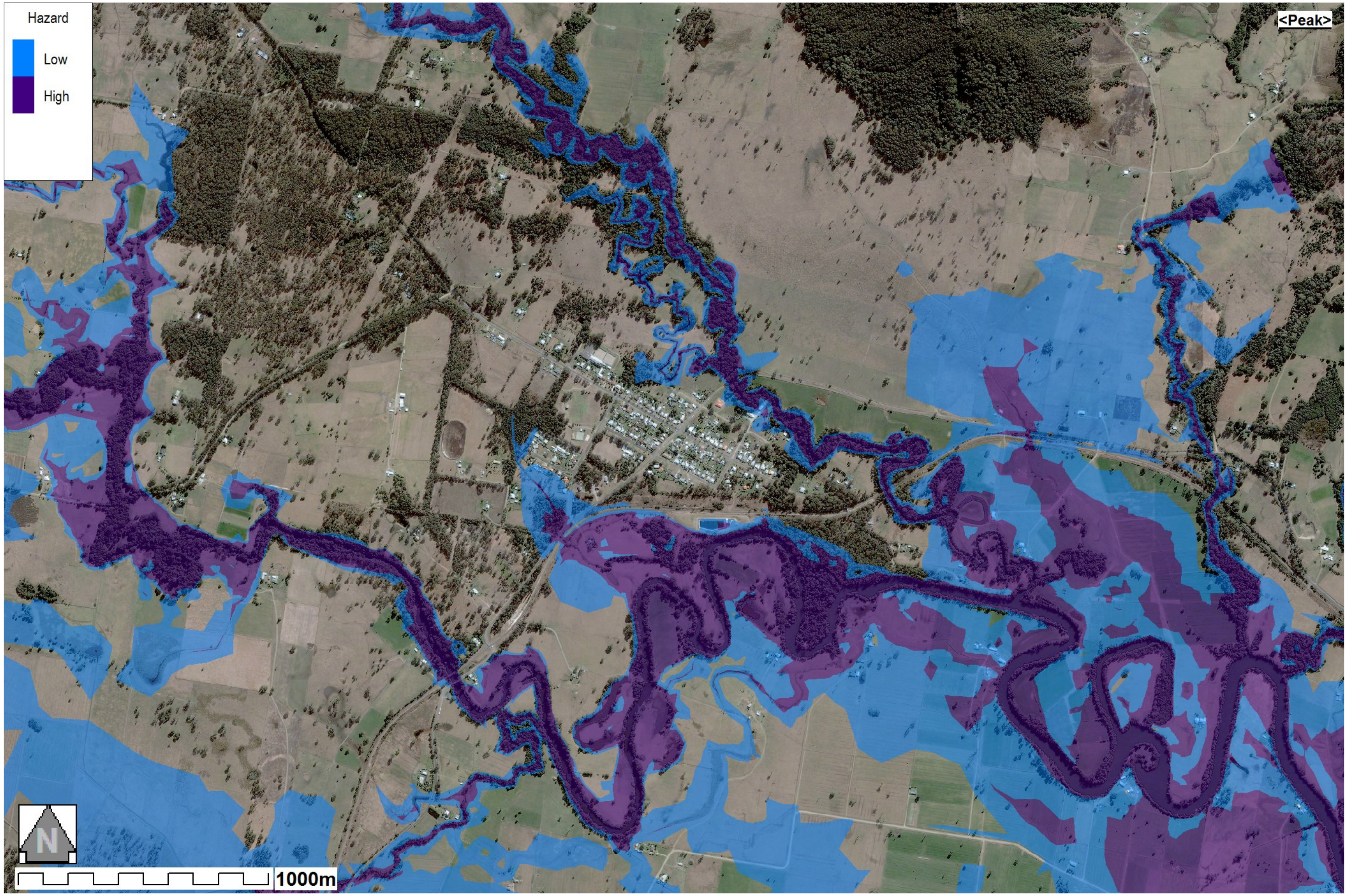

Figure B10 : Provisional Hazard Map for the 1% AEP flood event, based on the requirements of the FPDM and GTCC LEP/D

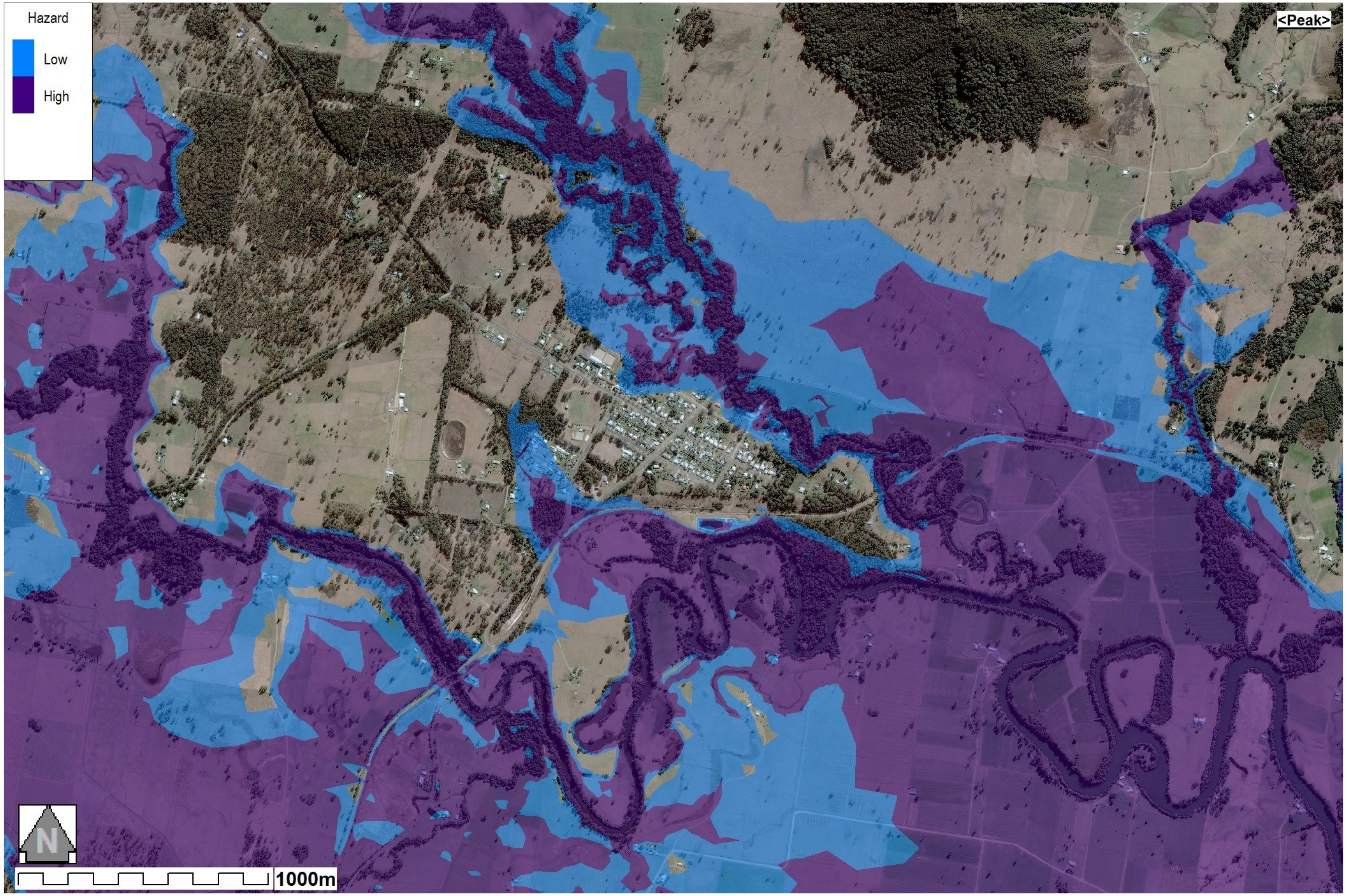

Figure B11 : Provisional Hazard Map for the PMF flood event, based on the requirements of the FPDM and GTCC LEP/D